



# SHO<sup>'25</sup>

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Occupational Safety and Hygiene

Proceedings Book



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# INDEX OF AUTHORS

| A                     |               |
|-----------------------|---------------|
| Abreu, D.             | 145           |
| Alves de Matos, S.    | 109           |
| Alves, H.             | 145           |
| Alves, R.             | 74            |
| Alves-Pereira, M.     | 125           |
| André, S.             | 162           |
| Azevedo, M.           | 11            |
| B                     |               |
| Bakker, H.            | 125           |
| Barbosa Fernandes, J. | 116           |
| Bento, J.             | 116           |
| Bernardino, R.        | 145           |
| C                     |               |
| Camarinha, S.         | 145           |
| Cardoso, C.           | 82            |
| Cervantes, R.         | 104           |
| Costa, F.             | 54            |
| Costa, I.             | 145           |
| D                     |               |
| Dardaghani, M.        | 24            |
| Dias, M.              | 104           |
| Dias, S.              | 182           |
| Dinis, B.             | 170           |
| Duarte Costa, F.      | 92, 97        |
| Duarte, Ana S.        | 109           |
| Duarte, J.            | 60            |
| F                     |               |
| Faria, Helena         | 41            |
| Faria, Hélia          | 1, 41, 48, 82 |
| Ferreira, A.          | 11, 24        |
| Ferreira, S.          | 151           |
| Figueiredo, João P.   | 11, 24        |
| Fulgêncio, V.         | 74            |
| G                     |               |
| Gamelas, C.           | 162           |
| Gomes, B.             | 104           |
| L                     |               |
| Lagoa, M.             | 116           |
| Laranjeira, P.        | 1, 41, 48, 82 |
| M                     |               |
| Martins, L.           | 74            |
| Matos, P.             | 54, 92, 97    |
| Melo, D.              | 145           |
| Merca, R.             | 133           |
| Moreira, F. M.        | 11, 24        |

| N                            |               |
|------------------------------|---------------|
| Nedélka, T.                  | 1             |
| Noboa-Lasso, Maria de L.     | 191           |
| Nunes, S.                    | 162           |
| O                            |               |
| Ochoa Leite, C.              | 116           |
| Oliveira e Silva, B.         | 54, 92, 97    |
| Oliveira, P.                 | 170, 182      |
| Oliveira, S.                 | 54, 92, 97    |
| P                            |               |
| Pardo-Ferreira, María del C. | 33            |
| Paulo Borges, D.             | 116           |
| Peixoto, J.                  | 54, 92, 97    |
| Pena, P.                     | 104           |
| Pereira, A.                  | 133           |
| Pereira-Sousa, P.            | 125           |
| Pires, L.                    | 116           |
| Q                            |               |
| Quito, J.                    | 151           |
| R                            |               |
| Ramos, Ana S.                | 116           |
| Rebelo, M.                   | 41            |
| Ribeiro, F.                  | 116           |
| Rocha, L.                    | 116           |
| Rodrigues, S.                | 60            |
| Rubio-Romero, Juan C.        | 33            |
| Rufo, João C.                | 116           |
| S                            |               |
| Saldanha, Nuno A.            | 109           |
| Salguero-Caparrós, F.        | 33            |
| Sardo, A.                    | 145           |
| Semedo, C.                   | 133           |
| Silva, L.                    | 145           |
| Silva, M.                    | 182           |
| Sousa Lima, João P.          | 116           |
| T                            |               |
| Teixeira, C.                 | 182           |
| Teixeira, P.                 | 170           |
| Tierra-Arévalo, José M.      | 33            |
| V                            |               |
| Vasconez, E.                 | 191           |
| Viegas, C.                   | 104           |
| Viegas, S.                   | 104           |
| Vieira, C.                   | 1, 41, 48, 82 |
| Z                            |               |
| Zoleykhæi, M.                | 60            |

|                                                                                                                                                         |     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Comparative analysis of legal framework on work accidents and occupational diseases in the Czech Republic and in Portugal                               | 1   |
| Evaluation of the Exposure of Wood Industry Workers to Ultrafine Particles in the Central Region                                                        | 11  |
| Exposure to particles and environmental pollutants, their effects on health - Case study in the Port of Figueira da Foz                                 | 24  |
| Functional resonance of the system in the formwork                                                                                                      | 33  |
| Attachment in the Interaction Between Active Seniors and Pets, and Its Role in Pet Clothing Choices: A Systematic Literature Review                     |     |
| Ergonomia Hospitalar e a Segurança do Paciente                                                                                                          | 41  |
| Chemical Risk Assessment Methods: A Comprehensive Review and Comparative Analysis                                                                       | 48  |
| Apoio psicossocial como arma fundamental do médico na reintegração laboral: relato caso                                                                 | 54  |
| Competency-based human resource management (CBHRM) methods in occupational safety and health: review, applications, and contribution                    | 60  |
| Impact of the Built Environment on the Perception of Caregivers of Children with Microcephaly in Specialized Outpatient Clinics: A Narrative Review     | 74  |
| Exposição Ocupacional a Agentes Químicos Cancerígenos, Mutagénicos e/ou Tóxicos para a Reprodução em Contexto Hospitalar                                | 82  |
| Adaptação Individualizada do Posto de Trabalho em Casos Clínicos Complexos: Um Estudo na Medicina do Trabalho                                           | 92  |
| Caracterização dos Acidentes de Trabalho com Risco Biológico num Hospital Terciário Português entre 2021 e 2024                                         | 97  |
| Airborne bacteria and particulate matter in poultry environments: a double threat to workers' health                                                    | 104 |
| Protocol for action of healthcare professionals with potential exposure to the hepatitis B virus in a portuguese tertiary hospital                      | 109 |
| Exposure Limit Value to Crystalline Silica – A Systematic Review                                                                                        | 116 |
| Dose-Response Relationship in Occupational Noise Exposures: The Distorted Quantification of Dose that Misinforms the Medical Community                  | 125 |
| Good practices identified in the literature to operationalise interventions aimed at preventing and managing psychosocial risks diagnosed by COPSOQ III | 133 |
| Time Until Certification of Occupational Diseases in Portugal: A Retrospective Study in a Hospital Center                                               | 145 |
| Smart Technologies in Household Solid Waste Collection: Reducing Occupational Risk for Collection Workers. A Review.                                    | 151 |
| Understanding the impact of Shift Work on the Sleep Quality of Municipal Police Officers                                                                | 162 |
| Occupational Health and Safety Management System in a Footwear Industry: Proposal and Implementation of an Integration Model                            | 170 |
| Sistema de Gestão da Segurança e Saúde no Trabalho (NP ISO 45001:2019): Proposta de modelo de gestão numa empresa do setor alimentar                    | 182 |
| Actigraphy in Worker Populations: A Short Review of Its Applications and Findings                                                                       | 191 |

## FOREWORD

We are delighted to welcome you to the 21st edition of the International Symposium on Occupational Safety and Hygiene – SHO'2025. This year, we proudly continue our hybrid format, enabling participants from around the globe to engage with our symposium and demonstrating our commitment to inclusivity and adaptability in the face of global challenges. The unwavering support of the Portuguese Society for Occupational Safety and Hygiene (SPOSHO) and our dedicated community has made this possible.

As we embark on the third decade of promoting advancements in occupational safety and hygiene, SHO serves as a distinguished platform for experts, practitioners, and enthusiasts to share knowledge, experiences, and the latest innovations in our field. This symposium fosters collaboration, innovation, and excellence.

We extend our heartfelt tribute to the visionary founder of SPOSHO, Professor A. Sérgio Miguel, whose pioneering spirit and dedication laid the groundwork for SHO's success and its influential role in shaping discourse around workplace safety and hygiene. Though he is no longer with us, his legacy of innovation and commitment continues to resonate within our community, and we honour his invaluable contributions.

The proceedings of the 21st edition of SHO feature diverse topics that reflect current challenges and advancements in occupational safety and hygiene. Key areas of focus include a comparative analysis of the legal frameworks governing work accidents and occupational diseases in the Czech Republic and Portugal, as well as the evaluation of ultrafine particle exposure among wood industry workers. Health impacts of environmental pollutants are explored through case studies, including the analysis of airborne bacteria and particulate matter in poultry environments, highlighting potential threats to worker health. Additional contributions emphasise ergonomic considerations in hospital settings and the psychosocial support necessary for reintegrating employees facing health challenges.

Innovative methodologies such as chemical risk assessment techniques, competency-based human resource management in occupational safety, and individualised workstation adaptations for complex clinical cases are examined. The proceedings also tackle critical issues such as exposure to carcinogenic and mutagenic chemicals in healthcare settings, the

impact of occupational noise on health, and the timelines for certifying occupational diseases in Portugal. Moreover, best practices for mitigating psychosocial risks and the integration of smart technologies in waste collection to reduce occupational hazards are discussed. Overall, these proceedings provide a comprehensive overview of empirical research, theoretical frameworks, and practical applications essential for advancing safety and health standards across various occupational settings.

This year, we received an impressive 126 submissions, with 119 accepted, reflecting an acceptance rate of 94%. The rigorous peer review process involved 253 reviews by our International Scientific Committee (ISC), comprised of 105 professionals from 13 countries, ensuring that accepted contributions meet the highest standards of scholarly inquiry and practical relevance. The participation of 380 authors from 18 countries underscores the symposium's global impact, bringing together diverse perspectives and cutting-edge research.

As in previous years, the papers will be published by SPOSHO in both the Symposium Proceedings and Abstracts books. Additionally, selected papers will be featured as book chapters by Springer Nature for the seventh consecutive year and indexed in SCOPUS. Outstanding contributions may also be published in the International Journal of Occupational and Environmental Safety (IJOES), enhancing the visibility of research presented at SHO.

We would like to express our sincere gratitude to all participants, organisers, and supporters who have made SHO a vital platform for knowledge exchange and advancement in our field. The enthusiastic participation and contributions from authors reflect our community's vibrant and collaborative spirit.

We also acknowledge the invaluable support from academic institutions, professional organisations, and companies, including the Portuguese Ergonomics Association (APERGO), the Portuguese Association for Safety (APSEI), the Commercial Association of Safety Engineers of Ljubljana (DVI Ljubljana), the European Network of Professional Safety and Health Organizations (ENSHPO), the Research Network on Working Conditions (RICOT), the Galician Society for the Prevention of Occupational Risks (SGPRL), Spanish Society For Health And Safety At Work (SESST), Brazilian Association of Occupational Hygienists (ABHO), the Portuguese Society of Labour

## FOREWORD

Medicine (SPMT), and the Portuguese Acoustics Society (SPA).

We also appreciate the support from various media partners, such as *Segurança* magazine, for their efforts in promoting this significant event.

As we reflect on our journey with SHO, we take pride in the impact we have made and the progress we have achieved. Our heartfelt thanks go out to all speakers, participants, sponsors, and organisers who have contributed to the success of this symposium over the years.

Let us all work together to make SHO'2025 a remarkable event as we continue to build on the solid foundation laid by our predecessors.

Porto, April 14<sup>th</sup>, 2025

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## PREÂMBULO

Temos o prazer de vos dar as boas-vindas à 21.<sup>a</sup> edição do Simpósio Internacional sobre Segurança e Higiene no Trabalho - SHO'2025. Este ano, continuamos orgulhosamente com o nosso formato híbrido, permitindo que participantes de todo o mundo se envolvam no nosso simpósio e demonstrando o nosso compromisso com a inclusão e adaptabilidade face aos desafios globais. O apoio inabalável da Sociedade Portuguesa de Segurança e Higiene Ocupacional (SPOSHO) e da nossa comunidade dedicada tornou isto possível.

Ao embarcarmos na terceira década de promoção de avanços na segurança e higiene no trabalho, a SPOSHO serve como uma plataforma distinta para especialistas, profissionais e entusiastas partilharem conhecimentos, experiências e as mais recentes inovações na nossa área. Este simpósio promove a colaboração, a inovação e a excelência.

Prestamos a nossa sincera homenagem ao visionário fundador da SPOSHO, o Professor A. Sérgio Miguel, cujo espírito pioneiro e dedicação lançaram as bases para o sucesso do SHO e o seu papel influente na formação do discurso em torno da segurança e higiene no local de trabalho. Apesar de já não estar entre nós, o seu legado de inovação e empenho continua a ressoar na nossa comunidade, pelo que honramos os seus inestimáveis contributos.

As atas da 21.<sup>a</sup> edição do SHO apresentam diversos tópicos que refletem os desafios atuais e os avanços na segurança e higiene no trabalho. As principais áreas de enfoque incluem uma análise comparativa dos quadros jurídicos que regem os acidentes de trabalho e as doenças profissionais na República Checa e em Portugal, bem como a avaliação da exposição a partículas ultrafinas entre os trabalhadores da indústria da madeira. Os impactos na saúde dos poluentes ambientais são explorados através de estudos de casos, incluindo a análise de bactérias transportadas pelo ar e de partículas em ambientes avícolas, salientando potenciais ameaças à saúde dos trabalhadores. Outras contribuições destacam considerações ergonómicas em ambientes hospitalares e o apoio psicossocial necessário para a reintegração de trabalhadores que enfrentam problemas de saúde.

São examinadas metodologias inovadoras, tais como técnicas de avaliação de riscos químicos, gestão de recursos humanos baseada em competências no domínio da segurança no trabalho e adaptações individualizadas de postos de trabalho para casos clínicos complexos. São ainda abordados temas críticos como a exposição a químicos carcinogénicos e mutagénicos em contextos de prestação de cuidados de saúde, o impacto do ruído ocupacional na saúde e os prazos de certificação de doenças profissionais em Portugal. Além disso, são discutidas as melhores

práticas para mitigar os riscos psicossociais e a integração de tecnologias inteligentes na recolha de resíduos para reduzir os riscos profissionais. De um modo geral, estas atas fornecem uma visão abrangente da investigação empírica, dos quadros teóricos e das aplicações práticas essenciais para o avanço das normas de segurança e saúde em vários contextos profissionais.

Este ano, recebemos um número impressionante de 126 submissões, com 119 aceites, o que reflete uma taxa de aceitação de 94%. O rigoroso processo de revisão por pares envolveu 253 revisões pelo nosso Comité Científico Internacional (ISC), composto por 105 profissionais de 13 países, assegurando que as contribuições aceites cumprem os mais elevados padrões de investigação académica e relevância prática. A participação de 380 autores de 18 países sublinha o impacto global do simpósio, reunindo diversas perspetivas e investigação de ponta.

Tal como nos anos anteriores, as comunicações serão publicadas pela SPOSHO nos Livros de Atas e de Resumos do Simpósio. Adicionalmente, os trabalhos selecionados serão apresentados como capítulos de livros pela *Springer Nature* pelo sétimo ano consecutivo e indexados no SCOPUS. As contribuições que se destacarem poderão também ser publicadas no *International Journal of Occupational and Environmental Safety* (IJOES), aumentando a visibilidade da investigação apresentada no SHO.

Gostaríamos de expressar a nossa sincera gratidão a todos os participantes, organizadores e apoiantes que fizeram do SHO uma plataforma vital para a troca de conhecimentos e o avanço no nosso campo. A participação entusiástica e as contribuições dos autores refletem o espírito vibrante e colaborativo da nossa comunidade.

Associação Portuguesa de Ergonomia (APERGO), Associação Portuguesa para a Segurança (APSEI), Associação Comercial dos Engenheiros de Segurança de Liubliana (DVI Liubliana), Rede Europeia de Organizações Profissionais de Segurança e Saúde (ENSHPO), Rede de Investigação sobre as Condições de Trabalho (RICOT), Sociedade Galega de Prevenção de Riscos Laborais (SGPRL), Sociedade Espanhola de Segurança e Saúde no Trabalho (SESST), Associação Brasileira de Higienistas Ocupacionais (ABHO), Sociedade Portuguesa de Medicina do Trabalho (SPMT) e Sociedade Portuguesa de Acústica (SPA).

Agradecemos também o apoio de vários parceiros de comunicação social, como a revista *Segurança*, pelo seu esforço na promoção deste importante evento.

Ao refletirmos sobre o nosso percurso com o SHO, orgulhamo-nos do impacto que causámos e dos

## PREÂMBULO

progressos que alcançámos. Os nossos sinceros agradecimentos vão para todos os oradores, participantes, patrocinadores e organizadores que contribuíram para o sucesso deste simpósio ao longo dos anos.

Vamos todos trabalhar em conjunto para fazer do SHO'2025 um evento notável, à medida que continuamos a construir sobre a base sólida estabelecida pelos nossos antecessores.

Porto, 14 de abril de 2025

*A Comissão Organizadora*

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# COMPARATIVE ANALYSIS OF LEGAL FRAMEWORK ON WORK ACCIDENTS AND OCCUPATIONAL DISEASES IN CZECH REPUBLIC AND IN PORTUGAL

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## Abstract

**Introduction:** Every year, thousands of workplace accidents occur in Portugal (PT) and the Czech Republic (CR), which can lead to permanent health consequences. **Objectives:** Present work aims to compare the legal framework regarding work accidents and occupational diseases in the CZ and PT, identify the main differences and similarities, and analyze the statistics of work accidents and diseases in both countries. **Methodology:** The work is based on a comparative analysis of national regulations on work accidents and occupational diseases, an analysis of statistics on work accidents and diseases. **Results:** The CZ emphasizes the prevention of work accidents, while PT focuses on post-accident support for workers in the form of compensation and rehabilitation. Statistics reveal differing areas of risk, with the CZ seeing frequent accidents in the manufacturing and transport sectors, while in Portugal, construction and fishing are the main areas of concern. Fatal accidents are more common in PT than in the CZ. **Conclusions:** The CZ and PT differ in their approaches to the prevention of work accidents and subsequent support for workers, with the CZ focusing on prevention and PT on compensation and rehabilitation. Cooperation between both countries may serve as a foundation for improving worker protection.

**Keywords:** work accident, occupational disease, health and safety at work.

## Introduction

Workplace accidents and occupational diseases are a serious issue with far-reaching consequences for both individuals and society as a whole. Every year, thousands of workplace accidents occur in Portugal and the Czech Republic, which can lead to permanent health consequences, loss of work performance, or even death. In addition, occupational diseases, resulting from long-term exposure to harmful factors in the work environment, are also a significant problem that often remains inadequately addressed. Different countries have different legal frameworks and approaches to protecting workers from these risks. This study focuses on comparing the legal frameworks of the Czech Republic (CZ) and Portugal (PT) in the area of workplace accidents and occupational diseases. The aim is to identify key differences and similarities in the legal regulations of both countries, further identify the role of the various control and support institutions involved in worker protection, and evaluate the statistics of workplace accidents in each country.

## Legal framework

### Concepts in CZ

The following terms are included in Czech legislation in Act No. 262/2006 Coll., the Labour Code:

**Work accident (Pracovní úraz).** A work accident is a health impairment or death of an employee that occurs:

- independently of their will;
- due to short-term, sudden, and violent external influences;
- while performing work tasks or in direct connection with them.

Performing work tasks:

- performance of work duties arising from the employment relationship and from agreements on work performed outside of the employment relationship;
- activities that are the subject of a business trip;

- activities performed for the employer at the initiative of a trade union, employee council, or health and safety representative;

In direct connection with the performance of work tasks:

- actions necessary for performing work and actions typical or necessary before starting work or after its completion;
- actions customary during breaks for meals and rest carried out on the employer's premises;
- examinations by a healthcare provider conducted at the employer's request or examinations related to night work, first aid treatment, and the journey to and from it;

Actions in direct connection with the performance of work tasks are not:

- travel to and from work;
- meals;

Fatal work accident:

- such health impairment, the consequences of which caused the employee affected by the accident to die no later than one year after the incident.

### **Occupational diseases (Nemoc z povolání):**

- it is a disease arising from adverse effects of chemical, physical, biological, or other harmful influences, provided that it occurred under the conditions specified in the list of occupational diseases;

The list of occupational diseases is divided into 6 chapters, each containing a different number of items. It consists of simple tables with the names of individual occupational diseases and the conditions under which they occur.

The List of Occupational Diseases is included in the Czech Republic legislation in Government Regulation No. 290/1995 Coll.

- Chapter I: Occupational diseases caused by chemicals;
- Chapter II: Occupational diseases caused by physical factors;
- Chapter III: Occupational diseases related to the respiratory system, lungs, pleura, and peritoneum;
- Chapter IV: Occupational skin diseases;
- Chapter V: Occupational infectious and parasitic diseases;
- Chapter VI: Occupational diseases caused by other factors and agents.

### **Concepts in PT**

The following terms are included in Portuguese legislation in Law no. 98/2009 of 04 September:

#### **Work accident (Acidente de trabalho):**

- An accident that occurs at the workplace and during work hours, resulting directly or indirectly in bodily injury, functional disturbance, or illness, which leads to a reduction in work capacity or earnings, or to death.

A work accident is also considered to occur in the following cases:

- During the journey to or from the workplace;
- Routes normally used and the time typically spent by the worker;
- Between any of their workplaces, in the case of having more than one job;
- Between their usual or occasional residence and the facilities that constitute their workplace;
- Between any of the locations mentioned in the previous point and the place of payment of the salary;
- Between the location where, by the employer's instructions, the worker performs any work related to their job and the facilities that constitute their usual workplace or their usual or occasional residence;
- Between the workplace and the place of the meal;
- Between the location where, by the employer's instructions, the worker performs any work related to their job and the facilities that constitute their usual workplace or their usual or occasional residence;
- Occupational accidents that occurred during interruptions or deviations from the normal route.
- While performing spontaneously provided services that may result in economic benefit for the employer;
- At the workplace when attending a professional training course;

- At the location of wage payment, while the worker remains there for that purpose;
- At the location where the worker is to receive any form of assistance or treatment due to a previous accident;
- While seeking employment during the time credit granted by law to workers undergoing the termination of their employment contract;

#### **Occupational disease (Doença profissional):**

- Occupational disease is one that is listed in the List of Occupational Diseases and that results from the worker being exposed to the respective risk due to the nature of the industry, activity or conditions, environment and techniques of the usual work;
- Furthermore, any bodily injury, functional disturbance, or disease not included in the list, provided it is proven to be a necessary and direct consequence of the activity performed and does not represent normal wear and tear of the body.

The list of occupational diseases is divided into 5 chapters, in this list we can find individual risk factors, diseases or other clinical manifestations and characterisation (indicative timeframe), list of examples of work likely to cause the disease.

The List is included in the Portuguese legislation in Regulatory Decree No. 76/2007, of July 17:

- Chapter 1: Diseases caused by chemical agents;
- Chapter 2: Diseases of the respiratory system;
- Chapter 3: Skin diseases and others;
- Chapter 4: Diseases caused by physical agents;
- Chapter 5: Infectious and parasitic diseases.

#### ***Analysis of differences and convergence of legal frameworks in both countries***

The concepts of work accidents and occupational diseases in the Czech Republic and Portugal share several similarities but also exhibit notable differences due to variations in national laws and regulatory frameworks.

#### ***Work accident (Pracovní úraz vs. Acidente de trabalho)***

The definition of a work accident differs significantly between countries. In the Czech Republic, emphasis is placed on the fact that the work accident must occur independently of the employee's will, and that it results from a short-term, sudden, and violent external influence. This factor plays an important role when assessing a work accident. While the definitions in both countries use different wording, they essentially state that the work accident must occur during working hours, and both definitions mention that a work accident leads to health impairment or death.

As for situations that are also considered work accidents, such as the commute to work, other locations instead of the employee's usual workplace, or situations before and after working hours, the legal frameworks are similar in both countries. The exception is that in Portuguese legislation, it is stated that a work accident also includes situations where the employee deviates from the normal route in cases of satisfying the employee's necessary needs, force majeure, or unexpected events. From this perspective, the recognition of work accidents in Portugal is more lenient, whereas in the Czech Republic, these cases are not considered.

#### ***Occupational disease (Nemoc z povolání vs. Doença profissional)***

There are significant differences in the definitions of occupational diseases in Portugal and the Czech Republic. In the Czech Republic, the recognition of occupational diseases is governed by a list where these diseases are listed, with the only exception being acute poisoning caused by the harmful effects of chemical substances. In contrast, in Portugal, in addition to the diseases listed in the list of occupational diseases, they also recognize any injury, functional disturbance, or disease that is not on the list, as long as it is a necessary and direct consequence of the performed work activity and does not represent normal wear and tear of the body. This is one of the reasons for the higher number of occupational diseases in Portugal compared to the Czech Republic.

The Portuguese list of occupational diseases is divided into 5 chapters, which are diseases caused by chemical agents, respiratory factors, skin problems, physical agents, and infectious or parasitic diseases. In the Czech Republic, the division of chapters is similar, with the addition of a chapter that covers occupational diseases caused by other factors and agents. While the Czech list of occupational diseases only includes the conditions for the occurrence of diseases, the Portuguese list provides more detailed information, including clinical manifestations with a time frame, as well as a list of example jobs where these diseases may occur.

## Intervening bodies

### *Bodies intervening in accidents at work and occupational diseases in CZ*

#### *Bodies intervening in accidents at work in CZ*

The **State Labour Inspectorate (Státní úřad inspekce práce - SÚIP)** and the **Regional Labour Inspectorates (Oblastní inspektoráty práce - OIP)** are key institutions in the CR that oversee compliance with labour laws and regulations concerning workplace safety and health protection.

Act No. 251/2005 Coll. labor inspection, this law regulates the scope, powers and activities of the labor inspection, both at the SÚIP level and at the OIP level.

#### SÚIP

SÚIP is the central administrative body that coordinates and oversees the activities of the regional labour inspectorates in the Czech Republic. It ensures the implementation of inspection activities at the national level, standardizes procedures, and develops methodological materials for labour inspectors.

Main tasks:

- Establishes methodological guidelines for regional labour inspectorates and monitors their activities;
- Creation and oversight of state policy in labour law;
- Regularly publishes statistics related to workplace accidents, incidents, inspection activities, and violations of labour law;
- It participates in educating both employees and employers about legal regulations concerning labour law, workplace safety, and health protection;
- It creates recommendations for improving working conditions and ensuring workplace safety;

#### OIP

Regional bodies that carry out inspections at the local level. Each regional labour inspectorate is responsible for a specific geographical area, typically a region or a group of regions. The inspectorates are responsible for monitoring compliance with labour laws and workplace safety and health regulations within their area.

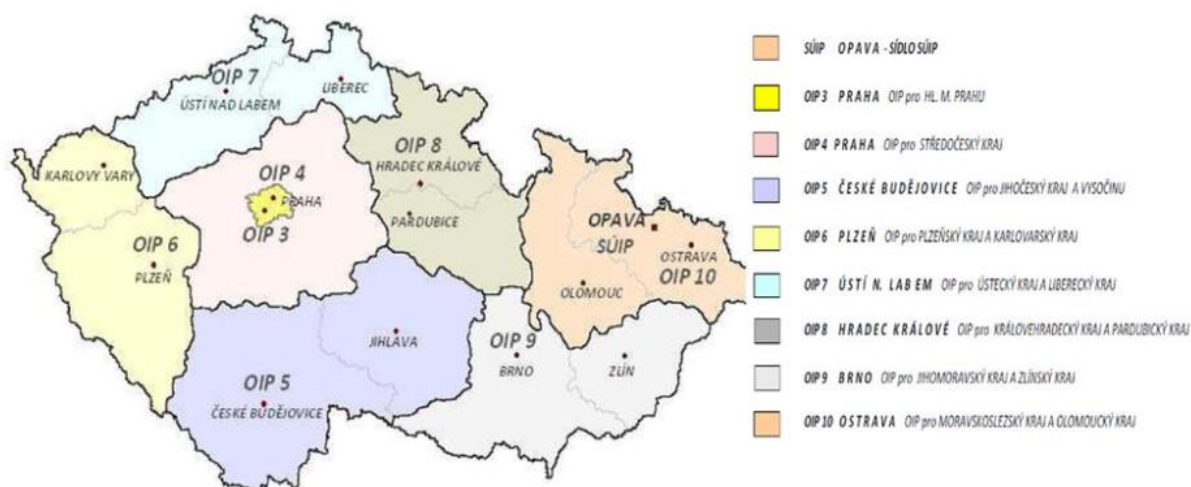


Figure 1. The division of OIP by regions (Státní úřad inspekce práce, 2012).

### ***Bodies intervening in occupational diseases in CZ***

Public health authorities (OOVZ) are institutions that carry out state administration in the protection of public health, to the extent and under the conditions specified by Act No. 258/2000 Coll., on the Protection of Public Health, as amended. In the Czech Republic, these are primarily the Ministry of Health and **Regional Hygiene Stations (KHS - Krajská hygienická stanice)**.

#### **KHS**

Regional hygiene stations are managed by the regional authorities and are subject to the Ministry of Health. Each station is headed by a director, who is responsible for carrying out duties in the region. There are various departments within the regional health station that focus on specific areas, such as: Department of Epidemiology, Department of Environmental Hygiene, **Department of Occupational Hygiene**, Department of Food Hygiene, Food Control Department, etc.

Main tasks of the field of occupational hygiene at KHS:

- Control of working conditions and working environment
- Assessment of occupational risks and factors
- Prevention of occupational accidents and diseases
- Carrying out measurement and evaluation of occupational risks
- Investigation of occupational accidents and diseases

### ***Bodies intervening in accidents at work and occupational diseases in PT***

#### **ACT**

The **Authority for Working Conditions (Autoridade para as Condições do Trabalho)**, whose acronym is ACT, is a Portuguese body under the guidance of the public administration, and is supervised by the Ministry of Labour, Solidarity and Social Security. ACT emerged from the former General Labour Inspectorate (Inspeção Geral do Trabalho – IGT) and the Institute for Safety, Hygiene and Health at Work (Instituto para a Segurança, Higiene e Saúde no Trabalho - ISHST). ACT is governed by the Regulatory Decree No. 47/2012, of 31 July.

Main tasks:

- Promote, control, and supervise compliance with legal, regulatory, and conventional provisions related to labor relations and working conditions, particularly those concerning occupational safety and health;
- Promote the development, dissemination, and application of scientific and technical knowledge in the field of occupational safety and health;
- Promote specialized training in the areas of occupational safety and health;
- Promote and participate in the development of occupational safety and health policies;
- In the case of workplace accidents, especially serious or fatal ones, ACT conducts investigations to determine the causes of the accident and assess whether the relevant safety regulations were followed;
- It participates in analyzing the circumstances of workplace accidents and recommends corrective measures.

#### **Others**

In Portugal, the ACT is the main body responsible for occupational safety and health, including the prevention of work-related accidents and diseases. However, the **DGS (Direção-Geral da Saúde)**, although not the main authority for workplace safety, also plays an important role in protecting workers' health, namely in the authorization of external occupational health services.

The **Instituto da Segurança Social (ISS)**, which is the Social Security Institute in Portugal, plays an important role in occupational safety, particularly when it comes to compensation and social security for workers who have suffered work-related accidents or illnesses due to the work environment.

In the case of fatal work accidents, the **Police** and the **Institute of Legal Medicine (IML - Instituto de Medicina Legal e Ciências Forenses)** are also involved in the investigation to examine the circumstances and prepare reports.

### Comparison of statistics on occupational accidents and diseases in CZ and PT

The statistics related to workplace accidents and diseases in Portugal and the Czech Republic, first, data will be presented on the number of serious workplace accidents in both countries, broken down by sector, as well as the number of fatal workplace accidents. Next, the focus will be on the number of serious workplace accidents and fatal workplace accidents according to the type of injury. The final part will address the number of occupational diseases and the most commonly diagnosed diseases. In the Czech Republic, statistical data on work accidents is collected by the State Labour Inspection Office, and data on occupational diseases is collected by the State Health Institute. In Portugal, this information is gathered by ACT or the National Institute of Statistics.

The following tables reveal that the most hazardous sector in terms of serious accidents in the Czech Republic is the manufacturing industry, with construction coming in second place, far behind. In Portugal, the situation is the opposite: construction ranks first, and manufacturing is in second place, with the difference compared to the Czech Republic being only little. In both countries, wholesale, retail, and motor vehicle repair industries are also significant sources of workplace accidents. The Czech Republic has a high accident rate in the transportation and storage sector, whereas in Portugal, surprisingly high numbers are found in administrative activities and support services.

**Table 1.** Number of serious accidents at work in CZ by activity sector 2020-2024 (SÚIP, 2023).

| odvětví (CZ-NACE)                              | závažné pracovní úrazy, graf č. 4.3.0 |              |              |              |              |              |            |            |            |            |
|------------------------------------------------|---------------------------------------|--------------|--------------|--------------|--------------|--------------|------------|------------|------------|------------|
|                                                | 2014                                  | 2015         | 2016         | 2017         | 2018         | 2019         | 2020       | 2021       | 2022       | 2023       |
| A. Zemědělství, lesnictví, Rybářství           | 112                                   | 80           | 96           | 77           | 78           | 65           | 69         | 50         | 55         | 42         |
| B. Těžba a dobývání                            | 6                                     | 0            | 13           | 24           | 23           | 19           | 10         | 15         | 5          | 1          |
| C. Zpracovatelský Průmysl                      | 454                                   | 398          | 418          | 370          | 347          | 318          | 239        | 243        | 226        | 216        |
| D. Výroba a rozvod elektrické a jiné energie   | 17                                    | 15           | 13           | 10           | 8            | 9            | 8          | 6          | 8          | 11         |
| E. Zásobování vodou; činnost s odpady          | 35                                    | 37           | 31           | 33           | 40           | 28           | 18         | 25         | 30         | 29         |
| F. Stavebnictví                                | 187                                   | 174          | 169          | 152          | 140          | 117          | 110        | 106        | 108        | 88         |
| G. Velkoobchod, maloobchod; opravy motor. voz. | 110                                   | 96           | 112          | 86           | 87           | 94           | 74         | 63         | 50         | 36         |
| H. Doprava a skladování                        | 149                                   | 159          | 144          | 127          | 137          | 124          | 96         | 98         | 96         | 96         |
| I. Ubytování, stravování a pohostinství        | 23                                    | 23           | 23           | 17           | 22           | 13           | 9          | 8          | 14         | 7          |
| J. Informační a komunikační činnosti           | 7                                     | 8            | 14           | 4            | 9            | 5            | 4          | 4          | 3          | 3          |
| K. Peněžnictví a pojišťovnictví                | 4                                     | 9            | 2            | 5            | 4            | 3            | 3          | 2          | 2          | 3          |
| L. Činnosti v oblasti nemovitostí              | 10                                    | 10           | 10           | 9            | 18           | 11           | 11         | 5          | 13         | 8          |
| M. Profesionální vědecké a technické činnosti  | 28                                    | 22           | 20           | 11           | 30           | 11           | 18         | 18         | 15         | 16         |
| N. Administrativní a podpůrné činnosti         | 45                                    | 56           | 62           | 54           | 46           | 31           | 31         | 27         | 21         | 29         |
| O. Veřejná správa a obrana; pov. soc. zab.     | 49                                    | 30           | 43           | 31           | 25           | 39           | 29         | 17         | 19         | 26         |
| P. Vzdělávání                                  | 40                                    | 44           | 44           | 31           | 38           | 39           | 23         | 20         | 31         | 39         |
| Q. Zdravotní a sociální Péče                   | 59                                    | 47           | 47           | 39           | 33           | 37           | 25         | 25         | 32         | 20         |
| R. Kulturní, zábavní a rekreační činnost       | 19                                    | 20           | 14           | 8            | 12           | 5            | 8          | 7          | 7          | 8          |
| S. Ostatní činnosti                            | 11                                    | 7            | 4            | 7            | 4            | 7            | 6          | 9          | 4          | 5          |
| nezjištěno                                     | 29                                    | 76           | 36           | 51           | 48           | 32           | 39         | 40         | 58         | 49         |
| <b>ČR</b>                                      | <b>1 394</b>                          | <b>1 311</b> | <b>1 315</b> | <b>1 146</b> | <b>1 149</b> | <b>1 007</b> | <b>830</b> | <b>788</b> | <b>797</b> | <b>732</b> |



**Table 2.** Number of serious accidents at work in PT by activity sector 2020-2024 (ACT, 2024).

| CAE                                                                                                     | 2020       | 2021       | 2022       | 2023       | 2024       | General Total |
|---------------------------------------------------------------------------------------------------------|------------|------------|------------|------------|------------|---------------|
| A - Agriculture, Animal Production, Hunting, Forestry and Fishing                                       | 25         | 23         | 38         | 28         | 13         | 127           |
| B - Extractive Industries                                                                               | 11         | 19         | 12         | 10         | 1          | 53            |
| C - Manufacturing Industries                                                                            | 134        | 180        | 191        | 161        | 53         | 719           |
| D - Electricity, Gas, Steam, Hot and Cold Water and Cold Air                                            | 0          | 6          | 0          | 2          | 0          | 8             |
| E - Water Collection, Treatment and Distribution; Sanitation, Waste Management and Pollution Control    | 7          | 12         | 21         | 6          | 2          | 48            |
| F - Construction                                                                                        | 145        | 219        | 194        | 207        | 58         | 823           |
| G - Wholesale and retail trade; Repair of motor vehicles and motorcycles                                | 50         | 64         | 64         | 57         | 27         | 262           |
| H - Transport and Storage                                                                               | 18         | 21         | 31         | 19         | 5          | 94            |
| I - Accommodation, food and similar                                                                     | 2          | 7          | 15         | 9          | 4          | 37            |
| J - Information and Communication Activities                                                            | 1          | 2          | 5          | 1          | 1          | 10            |
| K - Financial and Insurance Activities                                                                  | 1          | 0          | 1          | 0          | 0          | 2             |
| L - Real Estate                                                                                         | 2          | 6          | 8          | 4          | 0          | 20            |
| M - Consulting, Scientific, Technical and Similar Activities                                            | 11         | 12         | 13         | 6          | 4          | 46            |
| N - Administrative and Support Services Activities                                                      | 43         | 63         | 67         | 48         | 16         | 237           |
| O - Public Administration and Defense; Mandatory Social Security                                        | 6          | 4          | 3          | 5          | 2          | 20            |
| P - Education                                                                                           | 0          | 0          | 1          | 1          | 0          | 2             |
| Q - Human Health and Social Support Activities                                                          | 5          | 10         | 7          | 8          | 3          | 33            |
| R - Artistic, Shows, Sports and Recreational Activities                                                 | 3          | 1          | 1          | 3          | 1          | 9             |
| S - Other Service Activities                                                                            | 3          | 5          | 2          | 2          | 0          | 12            |
| T - Activities of Household Employers of Domestic Staff and Household Production Activities for Own Use | 0          | 0          | 0          | 0          | 0          | 0             |
| U - Activities of International Organizations and Other Extra-Territorial Institutions                  | 0          | 0          | 0          | 0          | 0          | 0             |
| Unknown                                                                                                 | 1          | 2          | 1          | 1          | 0          | 5             |
| <b>Total</b>                                                                                            | <b>468</b> | <b>656</b> | <b>675</b> | <b>578</b> | <b>190</b> | <b>2.567</b>  |

The most common consequences of fatal workplace accidents in Portugal are, by a large margin, multiple injuries. Other significant consequences include concussions, internal injuries, or shock. An anomaly occurred in 2019, when the consequence of a fatal workplace accident for seven individuals was drowning or

asphyxiation. As for serious workplace accidents, the most common consequence is clearly fractures, followed by multiple injuries and amputations. A large number of accidents also resulted in burns and frostbite, or also wounds and superficial injuries. In the Czech Republic, there is no statistics on the number of workplace accidents broken down by consequences, which, in my opinion, is a mistake; it could help advance solutions in this issue. However, various portals dealing with workplace safety and health protection indicate that the most common consequence of fatal workplace accidents is multiple injuries, and for serious workplace accidents, it is primarily fractures, burns, and head injuries.

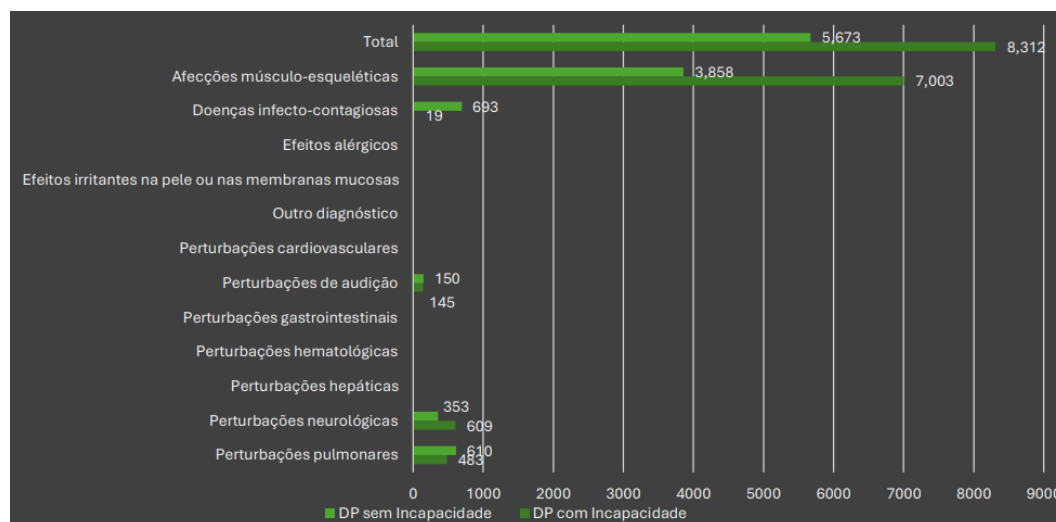


Figure 2. Occupational diseases by nature of disability and clinical diagnosis in PT 2023 (UGT, 2024).

Table3. Number of occupational diseases in the CZ 2014-2023 (Fenclová, 2023).

| Kapitola | Položka                   | Nemoc z povolání                                               | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 |
|----------|---------------------------|----------------------------------------------------------------|------|------|------|------|------|------|------|------|------|------|
| I.       |                           | NzP způsobené chemickými látkami                               | 1    | 3    | 2    | 5    | 6    | 9    | 7    | 6    | 6    | 9    |
| II.      |                           | NzP způsobené fyzikálními faktory                              | 336  | 374  | 349  | 480  | 527  | 695  | 767  | 665  | 547  | 520  |
|          | II.4                      | percepční kochleární vada sluchu způsobená hlukem              | 8    | 4    | 4    | 8    | 12   | 19   | 10   | 14   | 11   | 17   |
|          | II.6 – II.8               | nemoci z vibrací                                               | 100  | 136  | 103  | 145  | 155  | 178  | 217  | 199  | 155  | 154  |
|          | II.9 – II.10 <sup>1</sup> | nemoci z DNJZ                                                  | 224  | 231  | 233  | 316  | 346  | 483  | 535  | 445  | 374  | 341  |
|          |                           | ostatní NzP                                                    | 4    | 3    | 9    | 11   | 14   | 15   | 5    | 7    | 7    | 8    |
| III.     |                           | NzP týkající se dýchacích cest, plic, pohrudnice a pobřišnice  | 122  | 124  | 84   | 125  | 172  | 199  | 155  | 184  | 214  | 273  |
|          | III.1                     | pneumokoniózy způsobené SiO <sub>2</sub>                       | 71   | 71   | 49   | 64   | 78   | 82   | 64   | 94   | 111  | 166  |
|          | III.2                     | nemoci plic, pohrudnice nebo pobřišnice způsobené azbestem     | 15   | 6    | 7    | 17   | 12   | 23   | 12   | 17   | 22   | 23   |
|          | III.6                     | rakovina plic z radioaktivních látek                           | 1    | 1    | -    | -    | 1    | 2    | 1    | 2    | 2    | 8    |
|          | III.10                    | astma bronchiální včetně alergických onemocnění dýchacích cest | 29   | 40   | 20   | 36   | 75   | 81   | 67   | 62   | 67   | 56   |
|          |                           | ostatní NzP                                                    | 6    | 6    | 8    | 8    | 6    | 11   | 11   | 9    | 12   | 20   |
| IV.      |                           | NzP kožní                                                      | 71   | 67   | 80   | 131  | 168  | 166  | 177  | 181  | 149  | 179  |
| V.       |                           | NzP přenosné a parazitární                                     | 6405 | 6814 | 5473 | 294  | 193  | 153  | 171  | 205  | 117  | 230  |
|          | V.1                       | nemoci přenosné a parazitární s přenosem z člověka na člověka  | 6374 | 6790 | 5422 | 264  | 154  | 124  | 135  | 162  | 88   | 179  |
|          | V.2                       | nemoci přenosné ze zvířat na člověka                           | 5    | 9    | 15   | 14   | 27   | 14   | 28   | 24   | 16   | 22   |
|          | V.3                       | nemoci přenosné a parazitární vzniklé v zahraničí              | 26   | 15   | 36   | 16   | 12   | 15   | 8    | 19   | 13   | 29   |
| VI.      |                           | NzP způsobené ostatními faktory                                | 2    | 1    | 3    | -    | 1    | -    | 1    | 1    | 2    | 3    |
|          |                           | Nemoci z povolání                                              | 6937 | 7383 | 5991 | 1035 | 1067 | 1222 | 1278 | 1242 | 1035 | 1214 |
|          |                           | Ohrožení nemocí z povolání                                     | 64   | 56   | 52   | 77   | 78   | 60   | 92   | 55   | 57   | 36   |
|          |                           | Úhrnem                                                         | 7001 | 7439 | 6043 | 1112 | 1145 | 1282 | 1370 | 1297 | 1092 | 1250 |
|          |                           | Počet osob s hlášeným onemocněním                              | 6156 | 6996 | 5890 | 952  | 951  | 1034 | 1117 | 1051 | 911  | 1065 |

The figures for occupational diseases in Portugal and the Czech Republic cannot be compared in any way. Each country has different lists of diseases it recognizes as occupational diseases, and the criteria for recognizing these diseases also differ. This means that what is considered an occupational disease in one country may not be recognized in the other, and vice versa. This difference in the recognition of occupational diseases affects not only the statistics but also the approach to prevention, treatment, and compensation associated with these diseases. The vast majority of occupational diseases in the Czech Republic are caused by COVID-19, while in Portugal, they are primarily musculoskeletal disorders, such as Epicondylitis, Carpal tunnel syndrome, Elbow bursitis. Musculoskeletal disorders are among the second most common occupational diseases in the Czech



Republic; however, compared to the diseases in Portugal, the numbers are negligible. In Portugal, other common diseases include lung disorders and neurological conditions, which are not currently recognized as occupational diseases in the Czech Republic.

## Results and Conclusions

The results of the study highlight both differences and similarities between the legal frameworks of the Czech Republic and Portugal in the area of work accidents and occupational diseases. In both countries, the definitions of workplace accidents are similar, although Portugal recognizes a broader range of situations, such as unplanned deviations from the usual route to work. In the area of occupational diseases, Portugal adopts a more flexible approach, recognizing a wider range of diseases, including those not directly listed in the official register, whereas in the Czech Republic, the conditions for recognizing occupational diseases are stricter. Regarding the overall legal framework, the Czech Republic focuses on prevention, while Portugal primarily emphasizes a system of post-incident support for affected workers, including financial compensation and rehabilitation. Statistical data shows that in the Czech Republic, there is an annual decline in the number of serious workplace accidents and fatalities, while the situation in Portugal is less stable, with the country facing more frequent fatal workplace accidents. The study thus indicates that while the Czech legal framework contributes to effective prevention of workplace accidents, Portugal focuses on post-incident support for workers, which, combined with a broader definition of occupational diseases, leads to a higher number of registered diseases. Given the different approaches of individual countries in the area of occupational diseases, it would be desirable for the European Union to create a unified list of occupational diseases and methods for their recognition. The current situation, where each country has its own list of diseases and different criteria for their recognition, makes it difficult to effectively compare and analyze data. This difference between countries may lead to inconsistencies in monitoring occupational risks and providing adequate support to workers. Unification would allow for better protection of workers' health and facilitate tracking trends across all member states.

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## EVALUATION OF THE EXPOSURE OF WOOD INDUSTRY WORKERS TO ULTRAFINE PARTICLES IN THE CENTRAL REGION

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**Abstract:** Workplaces in an industrial environment encompass complex processes, in which new models of work organization and technologies are continuously introduced and are therefore exposed to different types of professional risks, which will affect the safety, health and well-being of workers, which will consequently determine the capacity for work. Study want evaluate the occupational exposure of workers in a timber industry to particles and atmospheric pollutants. Data collection consisted of two moments of investigation, firstly a questionnaire was applied to all workers in the timber industry under study, to analyze the symptomatology perceived by the same workers. The second moment consisted of the evaluation of the air quality parameters, resorting to the evaluation of atmospheric pollutants (CO<sub>2</sub>, CO, VOC, inhalable particles, breathable particles, and ultrafine particles) and of meteorological variables Temperature and Relative Humidity.

In terms of average values, the air quality parameters, for the most part, were found significantly above the exposure limit values, and the paint booth was where, in general, the highest values were found. Concentrations were generally higher inside the industry than outside. For preventing exposure to ultrafine particles, also emphasizing the need to define limit values for occupational exposure to them.

**Keywords:** occupational exposure; symptomatology; particulate matter; atmospheric pollutants; exposure limit.

### Introduction

Issues related to indoor air quality (IAQ) result from the interconnections between building materials and furniture, the activities carried out inside the building, the climate, and the occupants of the building. The Canadian Committee on Indoor Air Quality and Buildings states that a healthy indoor environment is one that contributes to productivity, comfort and a sense of health and well-being (COOHS, 2022).

In the European Union (EU), in 2020, 96% of the urban population was exposed to levels of fine particles above the reference value for health established by the World Health Organization. Exposure to fine particulate concentrations above the 2021 reference level resulted in 238 000 premature deaths in the EU (EEA, 2022)

In addition to affecting the incidence of disease and mortality, it is important to consider the loss of productivity at work and the additional economic burden, as well as the impact on agricultural crops and the damage caused to buildings and infrastructure (WHO, 2021).

People are exposed to air pollution in each microenvironment they live in, which is a function of the concentration of the pollutant and the time a person is exposed to it. Among the elements of risk assessment is exposure assessment, a process that involves assessing emissions, air pollution concentrations, population exposure, body burden, and doses of pollutants at the organ or cell level, as well as risks to the health. In some locations, concentrations of pollutants are low, but the overall contribution to exposure is high due to the longer time spent there, and even short periods spent in such locations result in high exposures (WHO, 2021).

Carbon monoxide (CO) is a colorless and odorless gas which, due to its high toxicity, makes it especially dangerous. Sources of CO can be diverse, including unvented oil heaters, gas heaters, leaky chimneys, gas ovens and water heaters, wood stoves, generators and other gas equipment, car exhaust and tobacco smoke (Seguel, 2017).

Carbon dioxide (CO<sub>2</sub>) is a colorless, tasteless, odorless and non-flammable gas that can accumulate in lower spaces, causing an oxygen deficiency. The concentration of CO<sub>2</sub> inside buildings represents an indicator of indoor air quality, the ability to exchange air flow and sufficient air renewal in closed spaces (IPCS, 2006; Emmerich, 2001).

Recent studies reveal physiological changes in the circulatory, cardiovascular, and nervous systems, including an increase in arterial pressure of CO<sub>2</sub> in the blood, an elevated blood pressure, an increase in heart rate and an increase in peripheral blood circulation at exposures in the range of 500 to 5000 ppm (Azuma, 2018).

In the various manufacturing processes, VOCs may be emitted in the form of gases, which are then inhaled, and the effects of this exposure are still unknown. Despite these unknowns, some of the adverse health effects include discomfort, irritation, respiratory symptoms, mutagenic and even carcinogenic effects (Rumchev, 2007). The definition of particulate matter, presented by the World Health Organization (WHO), is that “it consists of a mixture of particles that can be solid, liquid or both suspended in the air and represent a mixture of complex organic and inorganic substances” (WHO, 2021).

Particles are defined by their diameter for air quality regulation purposes. The smaller the dimension, the more likely it is to penetrate the respiratory tract and the greater the negative effects it can cause (Kim, 2015; APA, 2021).

The furniture production sector has evolved progressively in Portugal, and much of this evolution is due to the continuous implementation of improvements in production processes, which has increased its responsiveness, and consequently productivity and competitiveness (Pinho, 2015).

This industry involves a great deal of mechanical work, which is used to manufacture furniture and flooring, among others. Dust created during the manufacturing process can settle on floors, walls, and work surfaces in production facilities, or even, for dust with significantly reduced particle sizes, remain suspended in the air, which compromises the health of workers and creates additional hazards in the workplace by limiting visibility and increasing the risk of fire (Pędzik, 2021).

Based on the activities performed, the concentration and size of wood particles may vary. Considering the place of deposition, the particles can be defined as:

- Inhalable: With an aerodynamic diameter of less than 100 µm; enter the respiratory tract, reaching only the upper airways.
- Thoracic: With an aerodynamic diameter of less than 25 µm; they manage to go beyond the larynx, reaching the lungs and gas exchange regions of the lung.
- Breathable: With an aerodynamic diameter of less than 10 µm; are those most likely to reach and be deposited in the gas exchange region of the lung, namely the lung alveoli (US EPA, 2004).

Inhalable wood particles are deposited mainly in the nose, mouth, larynx, and pharynx, being strongly associated with nasal pathologies. Most attention has shifted to ultrafine particles (UFPs), as they have an aerodynamic diameter of less than 100 nm, giving them the ability to move to almost any organ, and although their role in the development of certain conditions is not yet known, it is recognized that their potential to harm health is great (Carvalho, 2022; Slezakova, 2019).

The health of people who are already vulnerable to air pollution can be adversely affected by short-term exposure (lasting one or more days) to these particles. These may suffer from coughing and chest tightness, as well as worsening respiratory complaints and temporary reductions in lung function. In most cases, the symptoms disappear along with the concentration of particles (Moreira, 2024; Atlas, 2018).

Despite recognizing the enormous potential that UFP must compromise health, its behavior and exact role as a source is still unknown. Their point of entry into the body is usually through from the lungs, through inhalation, reaching the alveoli and being distributed throughout the body through the circulatory system. (Schraufnagel, 2020; Kwon, 2020).

More recent studies report the effects that UFPs have on the cardiovascular and respiratory system, exacerbating the effects of asthma, the immune system's ability to respond when exposed to allergens, and even damage to deoxyribonucleic acid (DNA) due to its ability to penetration at the intracellular level (Li, 2016).

PFUs can also cause systemic inflammation, endothelial dysfunction, and clotting disorders, and can travel to the brain and cause brain dysfunction. In addition, exposure of the fetus in utero to UFPs may increase the risk of low birth weight (Schraufnagel, 2020).

The challenges posed by UFP include scientific challenges, associated with the complex processes involved, the necessary instruments which, due to their characteristics, are quite expensive. Their small size also affects how airborne PFUs move, taking on different shapes compared to fine particles, moving in random patterns more like gases. Legislative challenges are also considered, due to the lack of support that supports the standardization of measurements and the understanding of the sources and consequent effects, indicating the need for specific regulation of the UFP (Casseo, 2019; IQAir, 2022).

As a general objective, this project proposes to study the impacts of occupational exposure to particles and atmospheric pollutants on the health of workers in a logging company.

The specific objectives of this investigation were:

- Qualitatively and quantitatively characterize occupational exposure to particulate matter and air pollutants (CO<sub>2</sub>, CO, VOC, inhalable particles, breathable particles, and ultrafine particles).
- Describe the type of association between occupational exposure and the possible development of pathologies.
- Characterize the study population regarding respiratory and cardiovascular symptoms, among others.
- Evaluate the need for values stipulated by existing legislation and standardization.

### **Study design**

Regarding the type of study, this was a descriptive observational type, with a cross-sectional timeline.

The occupational exposure of workers belonging to a wood industry located in the central region of Portugal was evaluated, in which the data collected in that same industry was subsequently processed.

### **Population and sample**

The target population of the study consisted of 4 workers who performed their duties in the company in question, located in the central region of Portugal.

To integrate our study, the sample included, as inclusion criteria, workers who performed functions in the company, with continuous activity of 1 year. Locations that were not part of the production line, namely toilets and changing rooms, were excluded.

The applied sampling method was of the non-probabilistic type and as for the technique, this was for convenience.

As for the sample size, it consisted of 4 workers belonging to the company under study, who performed functions in the respective areas: production, assembly, and painting.

### **Instruments and data collection**

The study was carried out in the academic year 2023, with data collection taking place in the month of May.

Data collection consisted of two stages of investigation, the first being the application of a questionnaire (Annex I) addressed to all workers in the timber industry under study, to analyze the symptoms perceived by the workers. The second moment consisted of the evaluation of air quality parameters, resorting to the evaluation of atmospheric pollutants (CO<sub>2</sub>, CO, VOC, inhalable particles, breathable particles, and ultrafine particles) and meteorological variables Temperature (T°) and Relative Humidity (Hr) in 3 work areas inside the industry (production area, assembly area and painting area), in a total of 540 measurements, and outside a total of 60 measurements.

Measurements were taken over a period of 45 minutes per day in each work zone, for 4 days, with minute-to-minute sampling.

To carry out the measurements, important criteria were considered, such as the consideration of locations representative of the activities in question, placing the equipment in a central point of the space, at the level of the airways, also making a characterization of the location, and considering the operating periods of activities for measurement times (APA, 2009).

Portable real-time reading equipment was used for data collection. Regarding the parameters CO, VOC, CO<sub>2</sub>, the Q-Track Plus equipment, brand TSI, model 8552/8554 with serial number 8554-01061006 was used. The Particles Counters equipment, brand Lighthouse Worldwide Solutions, model 3016 LAQ with serial number 110144012, was used to assess the concentrations of particulate matter, and the equipment P-Track Ultrafine Particle Counter, brand TSI, model 8525 with serial number 8525-11170007, which has a 95 isopropyl alcohol solution reagent%.

Regarding the exposure limit values, according to the Portuguese Standard (NP) 1796:2014, the established limit value of CO<sub>2</sub> is 5000 *ppm*, that of CO is 10 mg/m<sup>3</sup>, VOC 0.1 mg/m<sup>3</sup>, for inhalable particles 10.0 mg/m<sup>3</sup> and for respirable particles 3.0 mg/m<sup>3</sup>. According to Decree-Law n. ° 243/86, of 20 August, the reference environmental conditions for temperature must oscillate between 18 and 22°C, while for relative humidity, it must oscillate between 50 and 70% (NP 1796,2014; Decree-Law No. 243/86).

Given the lack of reference values for the concentration of particulate material, namely ultrafine particles, the analytical average values recorded between the interior and exterior of the industry were assumed as a reference point.

### Statistical analysis

After the collection and subsequent treatment/analysis of the data obtained from the monitoring carried out, a statistical approach was taken, using all the information to create a database in specialized software (*IBM SPSS Statistics version 28.0*).

Descriptive statistics techniques were applied, namely frequency analysis (absolute and relative), calculation of measures of central tendency (simple arithmetic mean), measures of dispersion (standard deviation, amplitude, minimum and maximum value) and measures of tendency non-central (quantiles).

Inferential statistics techniques were also applied, resorting to an assessment of the assumptions, which can be framed in statistical tests of the parametric and non-parametric type. For this, a descriptive evaluation was necessary through the measures of kurtosis, by the Kurtosis statistic, and asymmetry, by the Skewness statistic. Finally, the normal distribution was also used as a measure for deciding on the choice of test.

In terms of hypothesis testing, *Kruskall-Wallis* tests, *Chi-square of independence*, *Wilcoxon Mann-Whitney*, *T-Student* for 1 sample and *Test of Covariance* were used.

Finally, regarding the extrapolation of the results to the population, we assumed a confidence level of 95% for a maximum random error of up to 5%.

### Results

Based on the application of pre-defined data collection instruments, we proceeded to evaluate the different workstations in relation to the different exposure limit values for CO<sub>2</sub> and VOCs. CO values are not represented in the table since no values were found within the industry. This assessment was then carried out to determine whether the exposure limit value for the worker had been exceeded, values which are shown in Table 1:



**Table 1.** Average concentrations of CO<sub>2</sub>, VOC, Respirable Particles, and Inhalable Particles in the different evaluated work zones

|                                                           |                 | <b>Production<br/>(n=180)</b> | <b>Assembly<br/>(n=180)</b> | <b>Painting<br/>(n=180)</b> |
|-----------------------------------------------------------|-----------------|-------------------------------|-----------------------------|-----------------------------|
| <b>CO<sub>2</sub><br/>(VLE=5000ppm)</b>                   | M (DP)          | 452.03<br>(53.111)            | 427.91 (54.169)             | <b>457.17 (54.397)</b>      |
|                                                           | [Min; Max]      | [391;665]                     | [387;653]                   | [387;707]                   |
|                                                           | Mean difference | -4547,967                     | -4572,089                   | -4542,833                   |
|                                                           | p-value         | 0.0                           | 0.0                         | 0.0                         |
| <b>VOC<br/>(LEV = 0.1<br/>mg/m3)</b>                      | M (DP)          | 0.0 (0.0)                     | 0.0 (0.0)                   | <b>12.22 (13.251)</b>       |
|                                                           | [Min; Max]      | [0.0;0.0]                     | [0.0;0.0]                   | [0.0;64.58]                 |
|                                                           | Mean difference | -                             | -                           | <b>12.112</b>               |
|                                                           | p-value         | -                             | -                           | <0.001                      |
| <b>Breathable<br/>particles<br/>(LEV = 3.0<br/>mg/m3)</b> | M (DP)          | 4,001 (4,781)                 | 6,342 (15,642)              | <b>29,029 (65,848)</b>      |
|                                                           | [Min; Max]      | [0.0;31.29]                   | [0.0;91.45]                 | [0.0;220.59]                |
|                                                           | Mean difference | 1.00                          | 3,342                       | <b>5.303</b>                |
|                                                           | p-value         | 0.003                         | 0.002                       | <0.001                      |
| <b>Inhalable<br/>particles<br/>(LEV = 10.0<br/>mg/m3)</b> | M (DP)          | 16,796<br>(31,645)            | <b>25,713 (69,582)</b>      | 21,682 (45,323)             |
|                                                           | [Min; Max]      | [0.01;260.33]                 | [0.0;370.33]                | [0.0;141.11]                |
|                                                           | Mean difference | 6,796                         | <b>15.713</b>               | 11,682                      |
|                                                           | p-value         | 0.002                         | 0.001                       | <0.001                      |

Test: t-Student for 1 sample; M – Average; SD – Standard Deviation; Min. - Minimum; Max.- Maximum; ELV - Exposure Limit Value

According to the results shown in Table 1 and using the t-Student test for 1 sample, it was found that the average CO<sub>2</sub> values in all stations were lower than the exposure limit value, with the highest average values verified in the “Painting” zone (457.17 ± 54.397), which is significantly below the limit (p<0.001).

In terms of VOCs, these showed significant values far above the exposure limit value (12.22 ± 13.251), namely in the “Painting” area, which is also the only place where values were measured.

Regarding respirable particles, it appears that the mean values are significantly above the exposure limit value, with the highest values found in the “Painting” zone (29.029 ± 65.848).

Finally, about inhalable particles, it is again verified that the mean values are significantly above the exposure limit value, with the highest values recorded in the “Assembly” zone (25.713 ± 69.582).

Next, we evaluated the average concentrations of CO<sub>2</sub>, Respirable Particles, Inhalable Particles, Ultrafine Particles and VOCs, values represented in table 2:

**Table 2.** Average concentrations of CO<sub>2</sub>, Temperature, Relative Humidity, Breathable Particles, Inhalable Particles, Ultrafine Particles and VOC in the different work zones.

| Work Zone            |               | Production<br>(n=180)       | Assembly<br>(n=180)    | Painting<br>(n=180)    | p-value |
|----------------------|---------------|-----------------------------|------------------------|------------------------|---------|
| CO <sub>2</sub>      | M (DP)        | 452.03 (53.111)             | 427.91 (54.169)        | <b>457.17 (54.397)</b> | <0.001  |
|                      | [Min;<br>Max] | [391;665]                   | [387;653]              | [387;707]              |         |
| Temperature          | M (DP)        | 19,848 (1,162)              | 19,240 (1,048)         | <b>20.192 (1.217)</b>  | <0.001  |
|                      | [Min;<br>Max] | [17.5;22.3]                 | [17.5;21.1]            | [17.8;22.5]            |         |
| Relative humidity    | M (DP)        | <b>54,096 (11,937)</b>      | 53,717 (15,305)        | 43.912 (5.606)         | <0.001  |
|                      | [Min;<br>Max] | [39.8;76.0]                 | [40.8;82.8]            | [37.4;58.3]            |         |
| Breathable particles | M (DP)        | 4,001 (4,781)               | 6,342 (15,642)         | <b>29,028 (65,848)</b> | <0.001  |
|                      | [Min;<br>Max] | [0.0;31.29]                 | [0.0;91.45]            | [0.0;220.49]           |         |
| Inhalable particles  | M (DP)        | 16,796 (31,645)             | <b>25,713 (69,582)</b> | 21,682 (45,323)        | <0.001  |
|                      | [Min;<br>Max] | [0.01;260.33]               | [0.0;370.33]           | [0.0;141.11]           |         |
| Ultrafine particles  | M (DP)        | <b>17953.17 (25400.717)</b> | 11796.06 (9404.573)    | 13047.84 (7030.412)    | <0.001  |
|                      | [Min;<br>Max] | [3390;194000]               | [1500;33200]           | [6210;47316]           |         |
| VOC                  | M (DP)        | 0.0 (0.0)                   | 0.0 (0.0)              | <b>12,218 (13,251)</b> | <0.001  |
|                      | [Min;<br>Max] | [0.0;0.0]                   | [0.0;0.0]              | [0.0;64.58]            |         |

Test: Kruskal-Wallis. M – Average; SD – Standard Deviation; Min. - Minimum; Max. - Maximum

Through the analysis of Chart 2, it was possible to verify that all pollutants and atmospheric particles showed significant differences ( $p < 0.05$ ).

About the CO<sub>2</sub> pollutant, it was found that the “Assembly” zone had lower average values compared to the “Painting” zone ( $d\bar{x} = 29.26\text{ppm}$ ) and “Production” zone ( $d\bar{x} = 24.12\text{ppm}$ ).

Regarding the Temperature parameter, the “Assembly” zone revealed lower average values compared to the “Painting” zone ( $d\bar{x} = 0.952\text{ °C}$ ) and the “Production” zone ( $d\bar{x} = 0.608\text{ °C}$ ).

Regarding the Relative Humidity parameter, the “Painting” zone presented lower average values compared to the “Production” zone ( $d\bar{x} = 10.184\%$ ) and the “Assembly” zone ( $d\bar{x} = 0.379\%$ ).

As for Breathable Particles, it was found that the average value was lower in the “Production” zone compared to the “Painting” zone ( $d\bar{x} = 25.027\text{ mg/m}^3$ ) and the “Assembly” zone ( $d\bar{x} = 2.341\text{ mg/m}^3$ ).

Analyzing the Inhalable Particles, it was found that the average value was lower in the “Production” zone compared to the “Assembly” zone ( $d\bar{x} = 8.917\text{ mg/m}^3$ ) and the “Painting” zone ( $d\bar{x} = 4.886\text{ mg/m}^3$ ).

Regarding Ultrafine Particles, the average value was lower in the “Assembly” zone compared to the “Production” zone ( $d\bar{x} = 6157.11\text{ppm}$ ) and the “Painting” zone ( $d\bar{x} = 1251.78\text{ppm}$ ).

Finally, regarding VOCs, it was found that the “Pintura” area was the only one where values were found compared to the other locations.

Subsequently, it was intended to verify whether there were exceedances of the legally established reference value for the thermal comfort parameters in the indoor air of the wood industry, whose values are shown in Table 3:



**Table 3.** Average concentrations of Temperature and Relative Humidity in the different work zones

|                        |            | Work Zone  |      |          |      |          |      |       |       |
|------------------------|------------|------------|------|----------|------|----------|------|-------|-------|
|                        |            | Production |      | Assembly |      | Painting |      | Total |       |
|                        |            | n          | %    | n        | %    | n        | %    | n     | %     |
| <b>Temperature (a)</b> | ≤17.99°C   | 3          | 10   | 23       | 76.7 | 4        | 13.3 | 30    | 5.6   |
|                        | [18-22] °C | 176        | 35.6 | 157      | 31.8 | 161      | 32.6 | 494   | 91.5  |
|                        | >22.00°C   | 1          | 6.3  | 0        | 0.0  | 15       | 93.8 | 16    | 3.0   |
|                        | Total      | 180        | 33.3 | 180      | 33.3 | 180      | 33.3 | 540   | 100.0 |
| <b>Humidity (b)</b>    | ≤49.99%    | 95         | 25.0 | 135      | 35.5 | 150      | 39.5 | 380   | 70.4  |
|                        | [50-70] %  | 44         | 59.5 | 0        | 0.0  | 30       | 40.5 | 74    | 13.7  |
|                        | >70.00%    | 41         | 47.7 | 45       | 52.3 | 0        | 0.0  | 86    | 15.9  |
|                        | Total      | 180        | 33.3 | 180      | 33.3 | 180      | 33.3 | 540   | 100.0 |

Caption: (a)(b) Chi-Square Test:  $\chi^2 = 52.994/97.015$ ;  $p < 0.001$ /  $p < 0.001$ ; n = number of samples; Temperature ≤ 17.99°C = Temperature less than or equal to 17.99°C; [18 – 22] °C = Temperature between 18 and 22°C; >22°C = Temperature above 22°C; Humidity ≤ 49.99% = Humidity less than or equal to 49.99%; [50-70] = Humidity between 50 and 70%; >70% = Humidity above 70%

Regarding the Temperature parameter, it was observed that of the 3 zones evaluated, in a total of 540 evaluations carried out, 46 (8.52%) had a temperature outside the legally established range [18-22°C]. Therefore, the work zones classified as “Assembly” and “Painting” had a greater number of cases in which the temperature was outside the legally established range.

Regarding the Relative Humidity parameter, it was observed that of the 3 areas evaluated, in a total of 540 specific evaluations carried out, 466 specific evaluations (86.3%) presented humidity outside the legally established range [50-70%]. Therefore, the work zones classified as “Painting” and “Assembly” showed a greater number of cases in which the humidity was outside the legally established range.

Subsequently, it was intended to evaluate the relationship between the concentrations of Respirable Particles, Inhalable Particles and Ultrafine Particles with indoor air and outdoor air, whose values are shown in Table 4:

**Table 4.** Concentrations of Respirable Particulates, Inhalable Particulates and Ultrafine Particulates in indoor and outdoor air.

|                             | Local   | No  | Average  | Standard deviation | p-value |
|-----------------------------|---------|-----|----------|--------------------|---------|
| <b>Breathable particles</b> | Inside  | 540 | 13.124   | 40,699             | <0.001  |
|                             | Outside | 60  | 0.886    | 0.494              |         |
| <b>Inhalable particles</b>  | Inside  | 540 | 21,397   | 51,341             | <0.001  |
|                             | Outside | 60  | 1.201    | 0.701              |         |
| <b>Ultrafine particles</b>  | inside  | 540 | 14265.69 | 16344.035          | <0.001  |
|                             | Outside | 60  | 19373.33 | 5434,693           |         |

Test: Wilcoxon-Mann-Whitney; N - Number of measurements; Z= -6.606/-6.524/-7.105

Through the analysis of Table 4, and using the Wilcoxon Mann-Whitney test, it was verified that the average concentration in each of the evaluated atmospheric parameters registered significant differences depending on the place where the measurements were carried out (indoor and outdoor).

The values registered were higher for Respirable Particles and Inhalable Particles inside the industry compared to outside it ( $d\bar{x}$ = 12.238 mg/m<sup>3</sup> for Respirable Particles and  $d\bar{x}$ = 20.196 mg/m<sup>3</sup> for Inhalable Particles), while for Ultrafine Particles the values outside the industry were higher compared to inside it ( $d\bar{x}$ = 5107.64ppm).

Next, it was intended to evaluate the relationship between the number of Breathable Particles, Inhalable Particles and Ultrafine Particles between the various work zones, whose values are presented in Table 5:

**Table 5.** Association between number of Breathable Particles, Inhalable Particles and Ultrafine Particles with different work zones.

| Work zone  |                              |                     | N<br>Breathable<br>Particles | N<br>Ultrafine<br>particles | N<br>Inhalable<br>Particles |
|------------|------------------------------|---------------------|------------------------------|-----------------------------|-----------------------------|
| Production | N<br>Breathable<br>Particles | Pearson correlation | 1                            | 0.478                       | <b>0.918</b>                |
|            |                              | p-value             | -                            | <0.001                      | <0.001                      |
|            | N Ultrafine<br>particles     | Pearson correlation | <b>0.478</b>                 | 1                           | 0.638                       |
|            |                              | p-value             | <0.001                       | -                           | <0.001                      |
|            | N Inhalable<br>Particles     | Pearson correlation | 0.918                        | <b>0.638</b>                | 1                           |
|            |                              | p-value             | <0.001                       | <0.001                      | -                           |
| Assembly   | N<br>Breathable<br>Particles | Pearson correlation | 1                            | -1,187                      | <b>0.994</b>                |
|            |                              | p-value             | -                            | 0.012                       | <0.001                      |
|            | N Ultrafine<br>particles     | Pearson correlation | <b>-0.187</b>                | 1                           | -0.184                      |
|            |                              | p-value             | 0.012                        | -                           | 0.013                       |
|            | N Inhalable<br>Particles     | Pearson correlation | 0.994                        | <b>-0.184</b>               | 1                           |
|            |                              | p-value             | <0.001                       | 0.013                       | -                           |
| Painting   | N<br>Breathable<br>Particles | Pearson correlation | 1                            | <b>0.071</b>                | <b>0.997</b>                |
|            |                              | p-value             | -                            | 0.346                       | <0.001                      |
|            | N Ultrafine<br>particles     | Pearson correlation | 0.071                        | 1                           | 0.080                       |
|            |                              | p-value             | 0.346                        | -                           | 0.285                       |
|            | N Inhalable<br>Particles     | Pearson correlation | 0.997                        | <b>0.080</b>                | 1                           |
|            |                              | p-value             | <0.001                       | 0.285                       | -                           |

#### - General characterization of the sample

For the collection of data for the present investigation, a wood furniture production industry, located in the central region of Portugal, was selected. The collections were carried out at the company's workstations where the 4 employees, all male, performed their duties.

The production station has the tasks of sanding the parts, cutting, maintenance, among others. The paint booth was the place where the parts that would later be used in the assembly station were painted. The assembly station would be the last step, where the parts are fixed to obtain the final product, which will be sent to the customer. The population that participated in the study consisted of 4 workers, all male (100%), with an approximate mean age of  $55.3 \pm 15.54$  years.

About working hours, 2 of the 4 workers (50% of respondents) worked an average of 7 hours a day, and 2 workers (50% of respondents) worked an average of 8 hours a day. In terms of educational qualifications, the 4 workers had completed “Basic Education”.

Regarding the time they worked at the company under study, the individuals worked for an average of  $35.5 \pm 17.45$  years, with a minimum time of 20 years and a maximum of 60 years. Regarding working hours/day, an average of  $7.5 \pm 0.58$  hours was recorded.

Regarding the use of Personal Protective Equipment (PPE), all workers stated that they always used them. However, workers indicated lack of use of certain types of PPE, such as protective glasses and visor (25%), ear protectors (25%) and respiratory protection mask (25%). Most workers did not wear safety boots (75%).

Regarding the improvement of symptoms when they go abroad, workers do not point out any changes in symptoms, a response that was also unanimously verified when asked if the manifestation of symptoms differed according to the season of the year. Finally, regarding smoking habits, 2 workers (50% of respondents) revealed to be active smokers

## **Discussion**

After analyzing the average values of CO<sub>2</sub> concentration, it was found that, in all workstations, the values were below the ELV, 5000ppm. This result was expected, given the existence of extraction systems, as well as the great natural ventilation existing in the place under study.

The workstation that presented the highest levels of CO<sub>2</sub> was the “Painting” area, which is to be expected, given the reduced space that this place presents, and being the one that is furthest from the entry point of natural ventilation. Even so and given that the company itself is small, the number of workers is low, and as a rule, workers do not work simultaneously in each area, the values obtained are not worrying, and are significantly below the limit value. of exposure.

About CO, its presence was only verified in outer space, and in this location the parameter was also below the ELV, 10 mg/m<sup>3</sup>. Although there are heating sources inside, the existence of extraction systems and strong ventilation inside the industry contributed to this result, and in all measurements the windows and doors were open.

Regarding the Temperature parameter, most average values (91.48%) were within the legally established temperature range [18-22] °C. Although the measurements were taken in the month of May, which is characteristic of higher temperatures, the fact that the measurements were taken in the morning (9h-12h), and that this space is heavily ventilated, contributed to the values obtained.

Regarding the Relative Humidity parameter, the results were quite different, with a wide range of values being verified, most of which are below the legally established range [50-70%]. As previously mentioned, the industry has a strong renewal of the air, in its interior, in which the windows and doors are open during the execution of the works, which contributed to the values obtained.

According to the Canadian Center for Occupational Health and Safety, relative humidity outside the parameters considered acceptable, in this case low, can cause discomfort to occupants. In this case, it would be important to review whether the ventilation system used will be the best for the space in question. It would also be important to consider the need to reorganize the space, namely the location of the equipment and the way in which the stations were divided, for more efficient ventilation (Moreira,2024; CCOHS, 2004).

About VOCs, these showed significant values well above the exposure limit value ( $12.22 \pm 13.251$ ), namely in the “Pintura” area, which is also the only place where values were measured. Obtaining these values and given that the measurements were made with the paint booth exhaust in operation, may be associated with incorrect

exhaustion, or clogging of the exhaust filters. Given the various sources of VOCs, such as the use of products such as solvents, paints, adhesives, and cleaning products, among others, it would be expected that the "Painting" area would have the highest values.

Some of the measures that should be adopted are the replacement of exhaust filters and the correct storage of solvents, paints and paint thinners, in a dedicated room equipped with local exhaustion, where they are well closed when not in use. (CCOHS, 2004). It will be relevant to pay attention to the purchase of water-based substitutes, which are starting to have more and more prominence in the market.

In general, exposure levels in the workplace tend to be higher than those of environmental exposure, and therefore the risk for some groups of workers may be higher than the average risk for the general population (Hämeri, 2009).

Regarding the UFP, the average values, comparing the different work zones, were higher in the "Production" zone. When the concentration between the exterior and interior environment was evaluated, these were higher on the exterior. This may indicate a possible contamination from the outside to the inside, given that the "Production" area, which registered the highest values, was close to the access point to the interior, and this structure could be introducing external contaminants.

Some of the measures that should be taken are to identify the sources of the UFP, to establish measures that aim to eliminate or reduce these sources. To avoid possible external contaminants, the use of extraction systems located as close as possible to the source should be considered (Marval & Tronville, 2022).

About respirable particles, the average values ( $29.029 \pm 65.848$ ) they were significantly above the exposure limit value ( $3 \text{ mg/m}^3$ ). The values were higher in the "Painting" zone, which raises questions, as with VOCs, about possible incorrect exhaust, or clogging of exhaust filters.

At the level of inhalable particles, the average values ( $25,713 \pm 69,582$ ) were also significantly above the exposure limit value ( $10 \text{ mg/m}^3$ ). In this parameter, the place that recorded higher values was "Assembly".

What could also justify the presence of such high values for these parameters could be the meteorology, because according to (Santos, 2017), periods of precipitation can contribute to the dissolution of contaminants, thus reducing their concentrations in the air. Unlike this scenario, and we can only consider the Temperature and Relative Humidity parameter, the record that was verified may have contributed to the greater presence of pollutants.

About the association between UFP, inhalable particles and respirable particles, the results indicated different levels of association between variables in different work zones. In the "Production" zone, there are positive correlations between the different variables. In the "Assembly" zone, there are positive and negative correlations, which indicates a greater complexity in the relationships. In the "Painting" zone, except for the positive correlation between the number of respirable and inhalable particles, the correlations were not statistically significant.

The positive correlation between inhalable particles and respirable particles can be explained with the measurement equipment used, as according to (Malings, 2018), a failure in the efficiency of counting for each particle size range can compromise its measurement range. This means that, with an increase in the number of respirable particles, it is expected that the number of inhalable particles will also increase, since the device may consider, when measuring, a certain range of particle size, being this within the respirable particles or inhalable, as part of the second, and vice versa.

In relation to the positive correlation found in the "Production" zone between UFP and inhalable particles (0.638), and the former with breathable particles (0.478), this could be due to the formation of secondary pollutants inside. There is still a lack of knowledge regarding the association between UFP and other pollutants in indoor environments. The infiltration of outdoor photo-oxidants into indoor environments, and the very interaction between VOCs indoors, can trigger new particle formation processes, which could be a source of increased UFP (Morawska, 2019).

## Conclusions

The importance of studying the occupational exposure of these pollutants in the wood industry is related to the exposure of these workers to different types of professional risks. Often motivated by production needs, it is common for workers to change temporary roles, which leads to their exposure to different types of contaminants. Based on the results obtained, we realize that, except for the values of CO<sub>2</sub>, CO, Temperature, and ultrafine particles, and for the latter there are no exposure limit values, the remaining values are significantly above the exposure limit values, and concentrations are higher inside the industry compared to outside. That said, specific measures are needed to improve the quality of the front air for each work zone.

It is essential that workers, and management themselves, are made aware of the importance of using PPE, to prevent and preserve their health. Attention should be paid to frequent and adequate cleaning of spaces, mainly to prevent the accumulation of dust on surfaces, machines, furniture, and equipment. It is also important, in addition to having ventilation and air extraction systems, that they are properly maintained, and for that it is essential to carry out frequent monitoring, to be able to identify situations that may become harmful, and even dangerous for its workers.

In terms of limitations found throughout the study, the first was undoubtedly the lack of information that was in accordance with the industry under study, and all the studies found were related to the combustion of wood. Another limitation felt was the lack of legislation regarding the exposure limit values for UFP, as well as not having evaluated the parameters at different times of the day, to understand how the variables behave in the absence of activities. Another limitation was the lack of evaluations with different meteorological variables, to see if there are changes in values in different seasons. It would also have been pertinent to apply the questionnaire to a company with a larger number of workers, to have a more credible sample.

Current guidelines only limit the major fractions of PM<sub>2.5</sub> and PM<sub>10</sub>, and current studies have increasingly supported the distinct behaviors that UFPs have from major fractions in the human body (Marval & Tronville, 2022). For this, there is a lack of epidemiological studies that study human exposure and bring together matrices that support the formation of guidelines for acceptable exposure levels, so that there is a standardization of methods, which will undoubtedly have to change in the future, with the growing concern for with this theme.

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## EXPOSURE TO PARTICLES AND ENVIRONMENTAL POLLUTANTS, THEIR EFFECTS ON HEALTH - CASE STUDY IN THE PORT OF FIGUEIRA DA FOZ

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**Abstract:** There is a growing concern with the evaluation of the external environment air due to the strong industrial and urban expansion. It is always desirable that the air is fresh and pleasant, that is, it does not have a negative impact on health. In the case of a port area, they are subject to various pollutants that are harmful to health, even more so if it is an international port. The main objectives were to evaluate the exposure of workers/residents in the surrounding area to outdoor air pollutants, PM<sub>2,5</sub>, PM<sub>10</sub>, CO<sub>2</sub> and ultrafine particles. The measurements were carried out in the port of Figueira da Foz. We checked whether there was any parameter outside the normal range and which of the points stood out. In this study, UFP levels were compared with other common air quality monitoring parameters. The results indicate that UFP values are high, with point 3 being the most notable. Degraded air quality poses a significant risk to human health, especially for children and the elderly. Although the primary sources of UFP are related, other preventive measures are needed to reduce these particles.

**Keywords** Occupational Exposure; Respirable particles; Health; Environmental Pollutants.

### Introduction

Work-related illnesses, which include work accidents, occupational illnesses, “work-related illnesses” and “illnesses aggravated by work”. It is a broad concept that encompasses all work situations that (negatively) influence the health of those who work. (Uva, 2006). The quality of the external environment is a concern that has been with man for many centuries, since the industrial revolution when “smog” occurred, the term used to define the accumulation of air pollution. It is always desirable that the air is fresh and pleasant, that is, it does not have a negative impact on health (Abreu, 2010). Over the last decade, a series of research and studies have focused on understanding the emission, formation, dispersion, exposure and effects of Ultrafine Particles (UFP). Most of these studies take place in European cities (Bruyninckx, 2021), with only a few emerging Asian cities, where the majority of the world's urban population resides. The main reason for such lack of attention/sloppiness in Asian cities is their focus on complying with strict regulations for pollutants, whose concentrations often exceed regulated limits.

Decree-Law 102/2010, of September 23, defines inhalable particles (PM<sub>10</sub>) as suspended particles capable of passing through a selective air intake, as defined in the reference method for sampling and measuring particles inhalable, standard EN 12341, with a cutting efficiency of 50% for a diameter of 10 µm and respirable particles (PM<sub>2,5</sub>) such as suspended particles capable of passing through a selective air intake, as defined in the method of reference for the sampling and measurement of respirable particles, standard EN 14907, with a cutting efficiency of 50% for a diameter of 2.5 µm (Ambiente, Qualidade do Ar Ambiente- Partículas em Suspensão) (Jones, Thornton, Mark, & Harrison, 2000).

In order to guarantee the protection of people from exposure to this pollutant, the 2014 NP 1796 standard established the exposure limit value (EV) for inhalable particles at 10,000 g/m<sup>3</sup> and for respirable particles at 3,000 g/m<sup>3</sup>. The main health problems mentioned in the European list of occupational diseases are: acute dermatitis due to contact with toxic products, contact urticaria, irritative contact dermatitis, conjunctivitis,



allergic rhinopathy, asthma, extrinsic allergic alveolitis, adenocarcinoma of the nasal cavity and paranasal sinuses and nasal sinus cancer (Amaral, 2012).

Ultrafine particles (UFP) are defined according to ISO/TC 146/SC2 as particles with a diameter less than or equal to 100 nm (0.1  $\mu\text{m}$ ). These particles pose a significant risk to human health when inhaled in high concentrations over time. UFP dominate particle number concentrations and surface area and are therefore capable of transporting large concentrations of condensed toxic air pollutants. It is likely that the redox-active components in UFP from fossil fuel combustion reach the cardiovascular system, leading to heart rate variability and blood pressure. (Delfino), also having an impact on the lungs, which can lead to lung cancer and/or lung inflammation. (Ohlwein, 2019). Carbon dioxide ( $\text{CO}_2$ ) is a colorless and odorless gas that, in high concentrations, can be harmful to workers' health. Although  $\text{CO}_2$  is a natural component of the air we breathe, prolonged exposure to high levels can cause a range of health problems. Such as respiratory problems, exposure to high levels of  $\text{CO}_2$  can lead to breathing difficulties, feelings of shortness of breath and increased respiratory rate. At the site under study, the area covered by the installations is immense, where the entry of goods is constant, whether by boats or heavy vehicles; both coming from different parts of the country or the world. There is therefore a risk of illness or accidents given the constant entry and exit. If preventive measures are not created and followed, the number of accidents will multiply, whatever their nature. Therefore, it was essential to monitor air quality at different points, as well as implement preventive measures, in order to safeguard the health of workers. As such, the main objectives of this research work were to evaluate the exposure of workers to air pollutants ( $\text{PM}_{2,5}$ ,  $\text{PM}_{10}$ ,  $\text{CO}_2$  and UFP) in suitable and strategically chosen locations and meteorological variables (Hr and  $T^\circ$ ).

## Materials and Methods

### Study design

This study was observational level II, descriptive-correlational and cross-sectional in nature, and the measurements were carried out in the municipality of Figueira da Foz, district of Coimbra.

### Population and sample

The sampling design was defined as non-probabilistic and as a convenience technique. The target population was made up of workers who travel to the port and inhabitants of the surrounding area, located in Figueira da Foz, in Coimbra. After a briefing together with some people responsible for the administration of the Port of Figueira da Foz, 4 points were chosen within the facilities, with the aim of covering as much area as possible and where there is the greatest movement of cargo and machinery.

### Instruments and Data Collection

This study was carried out during the months of October to July, the years 2023 and 2024, with the data collection period taking place in the months of April and May.

Firstly, several measurement points were defined, namely: point 1, next to the containers; point 2, next to the port administration offices; point 3, next to two warehouses where there was constant external circulation of machines and heavy vehicles and the last point, point 4, located at the westernmost point of the port.

After defining the measurement points, analytical data was collected. Data collection was based on the assessment of air quality, using the assessment of atmospheric pollutants ( $\text{CO}_2$ ,  $\text{PM}_{2,5}$  and  $\text{PM}_{10}$  and ultrafine particles-UFP) and the meteorological variables temperature (T) and relative humidity (Hr). (Hui Wang, 2023), (Viitanen, Uuksulainen, Koivisto, Hämeri, & Kauppinen, 2017), (Pasquiou, *et al.*, 2021), (Marval & Tronville, 2022).

Measurements at each point were carried out during the months of April and May, over a period of 30 minutes (Nota Técnica NT-SCE - 02, 2009), per point divided into two 15-minute measurements. The measuring equipment was placed next to the dock line, always preserving the port's proper functioning with maximum safety. At this stage, potential sources of contamination were also considered.

To collect data, four portable real-time reading devices were used. Regarding the parameters, CO<sub>2</sub>, T and Hr, the Velocicalc equipment, brand TSI, was used; to evaluate PM<sub>2,5</sub> and PM<sub>10</sub>, the Aerotrak Portable Particle Counter equipment, TSI brand, model 9550 was used; For ultrafine particles, the P-Track Ultrafine Particle Counter equipment, TSI brand, model 8525, which has a reagent with a 99.9% isopropyl alcohol solution.

The World Health Organization Standard, directive 2015/1480 of August 28, 2015, which amends some aspects of 2004/107/EC and 2008/50/8/EC, was considered as a reference. Decree-Law No. 243/86, of August 20, the reference comfort environmental conditions for T must range between 18 and 22°C, while Hr must range between 50 and 70% (Decreto-Lei n°243/86 de 20 de agosto, 1986).

### Statistical analysis

Statistical analysis of the data was carried out using the IBM Statistical Package for the Social Science (SPSS), version 29. When interpreting the statistical tests, a confidence level of 95% was considered for a maximum random error of up to 5%. A normality test was carried out and it was found that the data followed a normal distribution. This fact allowed the use of a linear correlation test for data analysis. Pearson correlation, also known as linear correlation, was performed in statistical tests. It is a statistical measure that quantifies the linear relationship between two continuous variables. This correlation is represented by the Pearson correlation coefficient (r) (J, 2023), whose value varies between -1 and 1. It is possible to understand through the value, predict the behavior of the variables under study. If  $r=1$ , it indicates a perfect positive linear correlation (when one variable increases, the other also increases consistently);  $r = -1$ : Indicates a perfect negative linear correlation (when one variable increases, the other decreases consistently);  $r = 0$ : Indicates that there is no noticeable linear correlation (the variables do not have a linear relationship).

Having been carried out, two more types of statistical tests, Student's T test and 1-Factor ANOVA test and the Scheffe test.

level 2

### Results and Discussion

In the table under analysis, we performed correlations with the aim of evaluating the behavior between the variables (T, CO<sub>2</sub>, Hr, PM<sub>2.5</sub>, PM<sub>10</sub> and UFP).

*Table 1. Pearson correlations between UFP and other pollutants.*

| N=1886            |      | T | CO <sub>2</sub> | Hr      | PM <sub>2,5</sub> | PM <sub>10</sub> | UFP     |
|-------------------|------|---|-----------------|---------|-------------------|------------------|---------|
| T                 | r    | 1 | -,392**         | -,780** | -,070**           | ,585**           | ,227**  |
|                   | Sig. |   | 0,000           | 0,000   | 0,002             | 0,000            | 0,000   |
| CO <sub>2</sub>   | r    |   | 1               | ,537**  | -0,041            | ,184**           | -,231** |
|                   | Sig. |   |                 | 0,000   | 0,077             | 0,000            | 0,000   |
| Hr                | r    |   |                 | 1       | -0,001            | -,476**          | -,189** |
|                   | Sig. |   |                 |         | 0,980             | 0,000            | 0,000   |
| PM <sub>2,5</sub> | r    |   |                 |         | 1                 | -,077**          | -,098** |
|                   | Sig. |   |                 |         |                   | 0,001            | 0,000   |
| PM <sub>10</sub>  | r    |   |                 |         |                   | 1                | -,055*  |
|                   | Sig. |   |                 |         |                   |                  | 0,016   |
| UFP               | r    |   |                 |         |                   |                  | 1       |
|                   | Sig. |   |                 |         |                   |                  |         |

This behavior is noticeable through the value of “r”. We can thus verify and divide into two distinct groups, that the coefficients of CO<sub>2</sub> and Hr with T are negative correlations. That is, when there is an increase in temperature, there is a decrease in carbon dioxide and relative humidity or vice versa. The most significant value originating from the Hr – T correlation with a coefficient of -0.780. It can easily be related to what happens in the environment, where the negative correlation between carbon dioxide and temperature is related to the behavior of gases in natural systems. When the temperature increases, the solubility of carbon dioxide in water decreases. This is because water molecules have a greater capacity to dissolve carbon dioxide at lower temperatures. Furthermore, biological processes, such as photosynthesis, also influence the concentration of CO<sub>2</sub> in the atmosphere. Plants and algae absorb CO<sub>2</sub> during photosynthesis, reducing its concentration. Therefore, when the temperature rises, the tendency is for CO<sub>2</sub> to be released from the water and ecosystems, resulting in a negative correlation between these variables.

The opposite happens regarding the correlation between Hr – CO<sub>2</sub> where the coefficient is 0.537, which is synonymous with a positive correlation, that is, when there is an increase in Hr there is also an increase in CO<sub>2</sub>. Where in turn can be explained through several factors. Firstly, the respiration of living organisms, including plants and animals, leads to the release of carbon dioxide.

The more organisms are present in an environment, the higher the concentration of CO<sub>2</sub>. Furthermore, the decomposition of organic matter also releases CO<sub>2</sub> and in the case of humid environments they are generally conducive to having more decomposing organic matter, which contributes to the positive correlation.

Finally, the solubility of CO<sub>2</sub> in water also plays a role; colder, nutrient-rich waters may contain more dissolved CO<sub>2</sub>, thus increasing the correlation with relative humidity. (Medeiros Filho), (Môso, 2018).

Next, the correlations between PM<sub>2.5</sub>, temperature, carbon dioxide and relative humidity were verified. We can see some similarity between the coefficients, all of which are negative, synonymous with negative correlations. That is, when one increases the other decreases, however in the case of the correlation coefficient between PM<sub>2.5</sub> and Hr of -0.001, we can say that it is an extremely weak negative correlation, due to it being close to zero. The correlations between PM<sub>10</sub> with temperature and carbon dioxide are positive correlations, with coefficients of 0.585 and 0.184, respectively. Due to the existence of a positive correlation between these variables, when one increases, the other also increases.

In the case of the correlation between PM<sub>10</sub> and Hr, we have a negative correlation with a coefficient of - 0.476. Noting that the concentration of fine particles is directly linked to air quality and human health, causing various complications/diseases.

The negative correlation between the variables (in particular, temperature, relative humidity, carbon dioxide, PM<sub>2.5</sub> and PM<sub>10</sub>) is relevant to understanding the health risks associated with exposure to these particles.

These correlations are relevant for environmental monitoring and the establishment of regulatory standards.

Cities and regulators must consider these relationships when setting policies to improve air quality and public health. (Montgomery, 2012), (Tabachnick, 2013).

Consequently, a correlation was verified between three variables (PM<sub>2.5</sub>, PM<sub>10</sub>, UFP) and their coefficients. In both cases, there is a negative correlation between the variables analyzed. That is, when PM<sub>2.5</sub> or PM<sub>10</sub> increases, UFP decreases or vice versa. This behavior was already expected due to previous tables and the short life cycle of PMs. For example, through an increase in relative humidity, there is a decrease in temperature, which can lead to a change in the PM under study, that is, with an increase in Hr, there is agglomeration or precipitation of PM, which can increase the size of the PM. PM<sub>2.5</sub> to PM<sub>10</sub> or to another size. (Hair Jr, 2014).

In the table under study, we can analyze the correlations between temperature, carbon dioxide, relative humidity, UFP.

In the case of the coefficient between T-UFP, the correlation coefficient is positive, meaning that there is an association between the variables, with a value of 0.227.

As the temperature increases, UFP levels also tend to increase, and vice versa. The closer the coefficient is to 1, the stronger this positive relationship.

A negative correlation, as is the case with the remaining correlations (CO<sub>2</sub>-UFP and Hr-UFP), when one variable increases, the other tends to decrease. With the coefficient of this relationship being -0.231 and -0.189, respectively.

As for the correlation coefficient of 0.128 (between Location-UFP), it indicates a weak positive association between UFP concentrations and the different locations where the samples were collected, with 4 different locations being analyzed within the port facilities.

When the UFP value increases, the values of the “local” variable also tend to increase, but this relationship is not significant.

The strength of the correlation is low, suggesting that other factors may be influencing these variables independently of each other.

The coefficient of 0.002 indicates an extremely weak correlation between UFP concentrations and climatic conditions (Climate).

In other words, changes in UFP concentrations are not significantly associated with climate variations.

We cannot therefore infer causality based on correlation alone. I also safeguard the possibility of external factors that also influence sampling (intense traffic, proximity to the sea, seasons).

In the table under analysis, table 2, where we have two sub-variables: “Sun” and “Cloudy”, originating from the “Climate” variable. It is important to note that the “Climate” variable is a variable that we were unable to control, hence the discrepancy in the sample values (N=18) and (N=1868), respectively. Still on this variable, “Climate”, it was composed of more sub-variables that were not relevant to the study in question, as they had an N=0.

**Table 2.** Particle Levels in relation to Climate.

|                         | Sun (N=18)            | Cloudy (N=1868)        | Diferença média | p-value |
|-------------------------|-----------------------|------------------------|-----------------|---------|
|                         | M± Dp                 | M± Dp                  |                 |         |
| <b>PM<sub>2.5</sub></b> | 1149244,61±431063,557 | 5260033,51±7545133,669 | -4110788,894    | 0,021   |
| <b>PM<sub>10</sub></b>  | 739658,83±936354,942  | 1013636,5±1197151,325  | -273977,668     | 0,333   |
| <b>UFP</b>              | 10163,33±552,183      | 10518,52±22800,361     | -355,189        | 0,947   |

Subtitle: M- Media; Dp- Standard Deviation; Test: T Student

Standard Deviation (Dp) is a statistical measure that expresses the degree of dispersion of a set of data. When the standard deviation is small, the values are closer to the mean. On the other hand, a larger standard deviation indicates greater variability in the data. (Triola., 2017). Therefore, in general, we expect the standard deviation to be close to the mean value of the results, but this may vary depending on the distribution of the data. Both in the context of PM<sub>2.5</sub>, PM<sub>10</sub> and UFP, the average values are quite far from the standard deviation.

As for the mean difference, it refers to the difference between the means of two populations or groups. A positive mean difference indicates that the first group's mean is greater, while a negative mean difference suggests that the second group's mean is greater. Noting that, also in the three pollutants under analysis, the values are always negative, indicating that the average value of the “Cloudy” variable is higher in relation to “Sun”.

The p-value (or p-value) is a number calculated from a statistical test that describes the probability of having obtained a specific set of observations if the null hypothesis were true. In other words, it indicates how likely it is that the data occurred under the null hypothesis. The lower the p-value, the more likely it is that the null hypothesis will be rejected. In this case, the p-value for PM<sub>2.5</sub> was 0.021, which indicates that there is statistical evidence to reject the null hypothesis, that is, there is no significant difference in the PM<sub>2.5</sub> means between the groups, suggesting a variance in the values between the conditions studied. As for PM<sub>10</sub>, a p-value of 0.333 was obtained, indicating that there are no significant differences, the same happened with UFP, expressed through a

p-value of 0.947. This discrepancy in the results obtained may be due to large differences between the observed values (for example, extremely sunny days and others that are very cloudy). It is also important to highlight that the study was carried out in spring, in a location located on the riverbank, which greatly influences natural climate variability. It can be concluded that there was no significant difference between the parameters evaluated during the study.

Now carrying out a more detailed analysis regarding the locations, in table 3, it is possible to observe the Average, Maximum and Minimum values, and the Standard Deviations.

The locations chosen for the study were: point 1, next to the containers; point 2, next to the port administration offices; point 3, next to the warehouses; and point 4, located at the westernmost point of the study site.

**Table 3.** Pollutant levels compared to the locations under study.

|                   |                               | Média       | Standard Deviation | Standard Error | Minimum | Max       |
|-------------------|-------------------------------|-------------|--------------------|----------------|---------|-----------|
| PM <sub>2,5</sub> | Containers(1)<br>N=483        | 3359053,23  | 744249,272         | 33864,514      | 1195384 | 4209430   |
|                   | Offices(2)<br>N=464           | 1859334,95  | 877201,190         | 40723,043      | 633595  | 2896460   |
|                   | Warehouses(3)<br>N=474        | 13764472,98 | 11166351,856       | 512887,527     | 933175  | 26899999  |
|                   | Westernmost point(4)<br>N=465 | 1799816,50  | 263457,103         | 12217,531      | 860135  | 2109924   |
| PM <sub>10</sub>  | Containers(1)<br>N=483        | 2627825,01  | 1166524,914        | 53078,721      | 1192000 | 4056603   |
|                   | Offices(2)<br>N=464           | 796182,86   | 692540,327         | 32150,378      | 70999   | 1571346   |
|                   | Warehouses(3)<br>N=474        | 465696,41   | 98738,054          | 4535,189       | 176986  | 741926    |
|                   | Westernmost point(4)<br>N=465 | 101889,07   | 15499,887          | 718,790        | 29000   | 120063    |
| UFP               | Containers(1)<br>N=483        | 10277,67    | 21220,581          | 965,570        | 487     | 128000    |
|                   | Offices(2)<br>N=464           | 2980,06     | 1566,491           | 72,723         | 193     | 10400     |
|                   | Warehouses(3)<br>N=474        | 13061,05    | 25723,29           | 1181,51        | 8,00    | 128000,00 |
|                   | Westernmost point(4)<br>N=465 | 15685,46    | 29270,56           | 1357,39        | 8,00    | 120000,00 |

Test: ANova 1 Fator

In a first analysis, PM<sub>2.5</sub>, it was possible to observe that the location with the highest Average and Maximum values were “Warehouses” (point 3). Place between bulk loads and solid loads, with constant movement of vehicles and machines. As for PM<sub>10</sub>, we found, as before, that the place with the highest Average value is also the place with the highest Maximum value, this being “Containers” (point 1). Regarding the UFP, the place with the highest Average value is “Point + West” (point 4), as for the highest Maximum value, the same was observed in point 3, “Warehouses”. As for the p-values obtained, we can state that there is a significant difference between the different pollutants in relation to the different points, since p-value  $\leq 0.05$ , therefore, it is possible to reject the null hypothesis. (Annex II). A Scheffe test was also carried out taking into account PM<sub>2.5</sub>, where it was possible to observe that the average values of the “Containers” are significantly higher than those of the “Offices” and the “Westernmost point” location (p-value < 0.001 in both cases). Furthermore, “Containers” have significantly lower mean values than “Warehouses” (p-value < 0.001). “Offices” have significantly lower mean values than “Warehouses” (p-value < 0.001). However, “Offices” have significantly higher mean values than “Westernmost point” (p-value = 0.999). “Warehouses” have mean values significantly higher than “Westernmost point” (p-value < 0.001).

The same test was also carried out for PM<sub>10</sub>, where it was found that the average values of “Containers” are significantly higher than those of “Offices”, “Westernmost point” and “Warehouses” (p-value < 0.001 in both

cases). “Offices” presented mean values significantly higher than those of “Warehouses” and “Westernmost point” (p-value < 0.001). However, “Offices” have significantly lower mean values than “Westernmost point” (p-value < 0.001). “Warehouses” have significantly higher mean values than “Westernmost point” (p-value < 0.001). The results suggest that “Containers” have superior performance compared to other locations. (Annex III)

It was also carried out in relation to UFP, where the average values of “Containers” are significantly higher than those of “Offices” (p-value < 0.001). Furthermore, “Containers” have significantly lower mean values than “Warehouses” (p-value = 0.289) and the “Westernmost point” region (p-value = 0.003). “Offices” present mean values significantly lower than those of “Warehouses” (p-value < 0.001) and “Westernmost point” (p-value < 0.001). (Annex IV).

Some of the results were expected, since, during the measurements carried out, there was movement of machines, heavy vehicles and also the presence of boats in operation, “connected”. It was noticeable, at the site under study, that there were different types of loads, the most relevant in this case being bulk loads. This type of load, being products moved without individual packaging and, especially in granulated form, gives rise to the deposition of dust in various places, particularly on the floor.

Due to these external factors present at the site, together with atmospheric factors (winds), dust is raised, thus spreading throughout the surrounding area. This causes atmospheric contamination, aggravated on hotter days, dry days, as previously noted, an increase in T leads to a decrease in Hr.

The only preventive measure observed, in order to mitigate these effects, was a “broom cart” that cleaned and washed the pavement, whenever necessary. The same happens on rainy or very humid days where the floor is naturally washed. Rain acts as a cleaning agent, removing dust from the surface. This process is widely observed in nature and in urban environments. This washing after rain has both beneficial and challenging implications for the study of air quality. Rain washes away dust particles and pollutants present on the surface of the pavement, helping to clean the environment. After rain, air quality may temporarily improve, especially where there is a large accumulation of dust, as in the case under study. Rainwater can react with pollutants deposited on the ground, releasing them back into the air. This can occur with substances such as nitrogen oxides, giving rise to acid rain. (Mirlean, 2000). To assess the impact of natural ground washing on air quality, it is important to take measurements before, during and after rain. In short, the natural washing of the ground by rain is a complex process, with positive and negative effects on air quality.

## **Conclusions**

Air quality is everyone's right, and because emission mitigation solutions exist and are effective, energetic action towards cleaner air, with everyone's participation, is essential (Lopes).

Through the results obtained in this study based on comparisons of UFP and other commonly monitored parameters, it can be concluded that it is necessary to take measures to improve air quality. The UFP values are high, with sampling point 3 being the most significant, and also the most expected due to the type of activity carried out. It was also possible to conclude that there is a relationship between different parameters that causes an increase or decrease, making it possible to understand this behavior, as well as the importance of various external factors. It is important to note that although the primary sources of UFP are related, they are not the only source of the problem. The degradation of air quality represents an important threat to human health, having been associated with the worsening of respiratory, cardiovascular and neurological diseases, especially in children and the elderly. Studies also indicate a correlation between exposure to some pollutants and the occurrence of different types of cancer. (Santana, 2012). In particular, due to its small size and ability to enter the bloodstream and lungs, it poses a high risk to human health. Therefore, the main objective is to develop activities within the scope of continuous improvement: improvement in safety to perform tasks and work activities, improvement in facilities and jobs and improvement through the promotion of health in the workplace. (Moreira, 2024; Pinto, 2012). Even if it is a challenge in relation to UFP, it should be reduced, since the most common preventive measures are not effective. During the study, some limitations were found, such



as the lack of specific legislation regarding reference values regarding the concentrations of atmospheric pollutants in outdoor air, as well as for ultrafine particles. As well as the short sampling time, this topic is extremely important, and the continuous monitoring of the parameters studied is extremely important. It is also important to create specific legislation, thus parameterizing limit values and making this type of studies constant.

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## FUNCTIONAL RESONANCE OF THE SYSTEM IN THE FORMWORK

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### Abstract

**Introduction:** The complexity of the construction sector necessitates a study that aligns with the activities carried out on-site. Resilience engineering provides tools to understand complex socio-technical systems from a novel perspective, to address unforeseen events. The primary objective of this study is to identify the functional resonance of the system in the formwork of a building slab. **Methodology:** The methodology employed in this article is grounded in the Functional Resonance Analysis Method (FRAM), which enables the analysis of the overall system resonance, considering functions, functional couplings, variability, and other factors. **Results and Discussion:** Thirty-four system functions have been identified in the formwork of a building slab. These functions, along with their variability, have been analysed, considering simple time and precision phenotypes, with a priority given to human functions. This analysis aimed to identify the functional resonance and its impact on the system. **Conclusions:** FRAM, as a tool of Resilience Engineering, has enabled the identification of critical points that could disrupt the complex socio-technical system of construction, adapting to the realities of the sector.

**Keywords:** Functional Resonance, FRAM, Functions, Construction.

### Introduction

Modern systems are complex entities where the interaction of their elements is fundamental to their proper functioning. Therefore, a study focused only on their parts would be inefficient. To improve the safety of these systems, it would seem important to adopt a systemic perspective that allows for the analysis of these interrelationships between elements to develop strategies that optimise the overall performance of the system (Hollnagel, 2021).

The construction sector is an example of these complex socio-technical systems, which, despite advances in the sector, are among the most dangerous worldwide. The complexity of its functions, tight deadlines and variable conditions have resulted in a high incidence of fatal occupational accidents (Lozano-Díez *et al.*, 2019). In the United States and Europe, one in five work-related deaths occurs in the construction sector (Huang *et al.*, 2022), (Mohandes *et al.*, 2022).

The construction sector has become an essential pillar for social development, with its infrastructure projects, housing development and large civil works. This sector in Spain in the year 2021 had registered a remarkable growth with more than 395000 active companies, with a turnover that exceeded 149000 million euros. The construction of buildings has been highlighted as the main activity considering the company and employment parameters representing around 38% of the total (Instituto Nacional de Estadística, 2024).

The remarkable complexity of the construction sector, as well as its high rates of occupational accidents worldwide (International Labour Organization - ILO, 2024; Ranasinghe *et al.*, 2020), require the implementation of safety management strategies coupled to reality. Resilience in these complex socio-technical systems is a predominant factor in the occurrence of incidents, therefore, studying it is fundamental to understand how the safety of the system can be guaranteed, identifying critical events and disturbances to manage them appropriately (Pilanawithana *et al.*, 2022),

Resilience Engineering allows for an in-depth analysis of the complex socio-technical system of the construction sector. Through the implementation of metrics such as system management and performance, it would allow to

identify the elements that contribute to the resilience of the system (Bergström *et al.*, 2015; Righi *et al.*, 2015), successfully facing unexpected events, and that would probably allow to improve the current situation, strengthening the system (Bragatto *et al.*, 2021; Xu *et al.*, 2023).

By integrating the concepts of variability and functional resonance, Resilience Engineering provides a valuable tool for understanding how complex socio-technical systems can adapt to and overcome disturbances. It differs from traditional approaches that focus on errors by considering the possibility of focusing on the positive factors that allow resilience to be generated in the system (Haavik *et al.*, 2019; Hollnagel *et al.*, 2015). Resilience Engineering has highlighted learning the right lessons from the right experiences (Patriarca *et al.*, 2018), where understanding and learning from daily work could strengthen workers' reactions to deal with unexpected events (Degerman & Wallo, 2024).

One of the Resilience Engineering tools that would allow the assessment of the complex socio-technical system of construction is the Functional Resonance Analysis Method (FRAM) due to its dynamism and versatility (Patriarca *et al.*, 2020), (Tierra-Arévalo *et al.*, 2023). The application of this new paradigm would allow the development of a holistic understanding of complex socio-technical systems, considering it as the basis for identifying and analysing the functions involved and their interdependencies. After analysing the disturbances, it would seem important to delve deeper into the functional resonance that occurs within the system, to understand its functioning and to propose mechanisms to achieve a resilient system that contributes to the improvement of occupational safety management (Hollnagel, 2021).

The main objective of this study is to identify the functional resonance of the system in the formwork of a building slab. The following research questions will guide the study:

What are the functions of the system in the formwork of a building slab?

What is the variability of system performance in the formwork of a building slab?

How does the functional resonance of the system appear in the formwork of a building slab?

This article is structured in four sections: introduction, methodology, results and discussion, and conclusions.

## Methodology

The methodology used to prepare this article is based on the “Functional Resonance Analysis Method” (FRAM). To do so, it was necessary to know the real performance of the system through documentary analysis and fieldwork, which were based on interviews and observations. For the documentary analysis, the legislation and regulations in force, the guides and manuals focused on the construction of structures, the websites of the main suppliers and subcontractors, as well as the safety plans provided by the collaborating companies were required. The fieldwork was carried out in 3 different construction sites of similar characteristics in the same province, where observations of the work were made and documented with photographs and on-site interviews. The 21 people participating in the interviews were selected according to their experience and their availability of time in the company, to collect the information to feed the model. The interviews were conducted using a script with questions that support the model.

FRAM made it possible to evaluate the complex socio-technical system of the construction sector by adjusting it to the reality of the system. An initial step was the definition of the purpose of the study, which had to be clearly defined, and which was related to the following 3 potential applications (Hollnagel, 2012):

- a) Retrospective for event analysis.
- b) Prospective risk assessment.
- c) System variability assessments or system re-design.

FRAM has been applied considering the following steps (Hollnagel, 2012; Melanson & Nadeau, 2019; Patriarca *et al.*, 2017):

### Step 1: Identification and description of system functions

The initial step was to become familiar with all the functions that were embedded within the complex socio-technical system, which enabled the objective determined by the system to be achieved. These functions were

varied and were determined by 6 aspects to be considered for each case: Input, Output, Precondition, Resources, Control and Time.

#### **Step 2: Identification of performance variability.**

After the identification of the detailed functions of the system, the characterisation of the potential variability and the actual variability of the system performance was carried out. For the characterisation of variability, simple phenotypes such as time and accuracy were considered. The variability characteristics could be presented according to the type of function. In this case they were performed considering human functions with high frequency and high amplitude. These functions were performed by workers in the workplace.

#### **Step 3: Aggregation of variability.**

According to the couplings of the system, the potential variability of a function was identified, which could have had different results than expected, due to upstream and downstream functional couplings, and which could therefore modify the behaviour of the system. The functional resonance analysis allowed for a holistic and realistic approach to the analysis of the system.

#### **Step 4: Managing variability.**

In this step, in accordance with the new safety paradigm, the amplification of the positive effects and the minimisation of the negative effects produced by the variability of the system's performance is proposed, with the aim of having a resilient system that allows the expected result to be obtained.

The principles immersed in this methodology were: the principle of equivalence of failures and successes, the principle of approximate adjustments, the principle of emergence and the principle of functional resonance.

### **Results and Discussion**

In accordance with the research questions posed, this section presents the results and discussion. Regarding the first question: What are the functions of the system in the formwork of a building slab?

Thirty-four functions of the formwork system in a building slab have been identified as follows: To enter the site, to dialogue with the manager, to order material from crane operator, to prepare material, to lift material, to move material to be installed, to indicate height, to open props, to position main formwork supports, to fasten main formwork supports, to position the ties, to define the height of the props, to install props, to adjust props, to measure levelling, to level the props, to position trenches, to lay boards, to extend the working platform, to extend main formwork supports, to extend ties, to add tilting supports, to project the layout upwards, to request machinery from a crane operator, to prepare machinery, to lift cutting machine, to cut boards and timbers, to complete areas, to install boards, to seal holes, to check stock, to verify quality, to collect tools, to release the formwork for use.

Of the 34 identified functions of the formwork system in a building slab, 29 primary functions are highlighted in colour and 5 secondary functions are shaded in Figure 1. These functions, which are part of this complex socio-technical system, do not necessarily develop in a linear manner as traditionally assumed. Instead, they adapt to the system's needs to ensure optimal performance and achieve the desired outcome. The functions themselves do not exhibit any defined hierarchy or sequence.

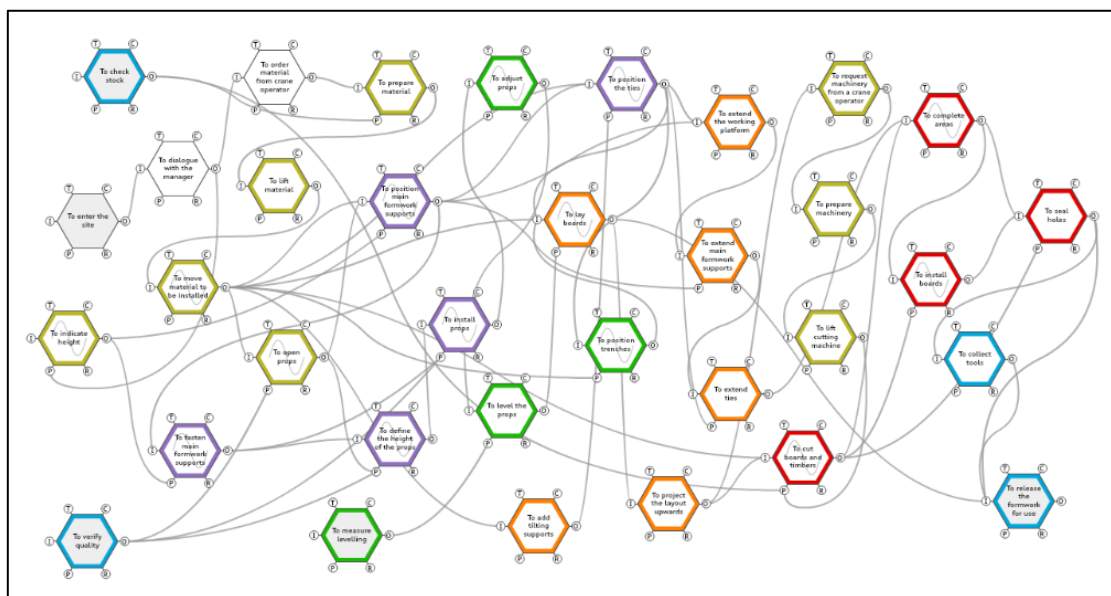
Regarding the second question: What is the variability of the performance of the formwork system in a building slab.

The variability has been determined by considering the simple phenotypes of time and precision. This variability is highlighted in the functions shown in Table 2. As an example, the variability determined in the function "To cut boards and timbers" is shown in Table 1.

**Table 1.** Example of the identification of variability in the function “To cut boards and timbers”.  
**Source:** Authors.

| No | Functions                 | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 27 | To cut boards and timbers | <ol style="list-style-type: none"> <li>1. The excessive dimensions of some boards, planks, and timbers can sometimes hinder handling and affect the cutting process, leading to imprecisions.</li> <li>2. If the cuts do not meet the exact requested dimensions, imprecisions will result.</li> <li>3. If the dimensions of a cut are larger than required, rework will be necessary, leading to delays.</li> <li>4. Conversely, if the dimensions are smaller than required, the cutting process will need to be restarted, resulting in delays.</li> </ol> <p>Exogenous:</p> <ol style="list-style-type: none"> <li>1. These imprecisions, if not properly managed, could lead to accidents.</li> <li>2. The repetition of these events throughout the workday due to fatigue could lead to imprecisions and, consequently, further delays.</li> <li>3. Periodic maintenance of the machinery is necessary to guarantee the cut.</li> </ol> |

The variability in the system's performance during the formwork of a building slab originates from the multiple couplings between functions throughout the entire system, as observed in Figure 1. The function of “To cut boards and timbers” presents the greatest number of options in which variability is embedded. This function also highlights exogenous variability, which is not necessarily present in all functions.



**Figure 1.-** Couplings of the system's functions in the formwork of a building slab.

**Source:** Authors.

Regarding the third question: How is the functional resonance of the system presented in the formwork of a building slab?

Multiple functional couplings upstream and downstream cause resonance in the system which could modify the behaviour of the system (Pardo-Ferreira *et al.*, 2020).

Table 2 presents the functional resonance when analysing the system with a holistic approach.

**Table 2.** Functional resonance of the formwork system in a building slab.

*Source:* Authors.

| No | Functions                          | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6  | To move material to be installed   | The material to be used is moved multiple times from its initial point until it reaches the plant. From there, workers will be responsible for transporting it to its installation point. This function of "To move material to be installed" could generate resonance in 7 downstream system functions. On certain occasions, due to the ease of transporting small elements first, an unnecessary wait and inefficiency could be generated in the function of "To position main formwork supports" and in the function of "To open props", since the elements of both functions need to be coupled together to be able to start the shuttering structure. Additionally, resonance could be generated in the function of "To add tilting supports" and in "To position the ties", as they are executed simultaneously, due to the placement of tilting supports on odd ties. Even the final phase of the shuttering, in the functions of "To position trenches", "To lay boards", and "To cut boards and timbers", could be impacted if the necessary corrective measures are not taken in time. |
| 7  | To indicate height                 | The function of 'To indicate height' must be executed with the utmost precision, as any confusion could lead to unnecessary work that would require a disproportionate amount of time to return the worksite to its normal conditions. The downstream function of 'To indicate height' could generate resonance in the functions of 'To position main formwork supports' as well as 'To fasten main formwork supports', which are practically the basis for extending the entire shuttering. The experience of some workers allows them to react favourably to the occurrence of these events, which encourages them to confirm that the marking is consistent with the characteristics of the shuttering to be carried out.                                                                                                                                                                                                                                                                                                                                                                      |
| 8  | To open props                      | The function of 'To open props' could generate upstream resonance in the function of 'To verify quality' with the aim of reinforcing the parameters established to determine the straightness of the props and ensure they are considered of quality. Downstream, the function of 'To define the height of the props' would be impacted first, since it would not be feasible to manipulate a prop that presents defects. Consequently, in second place, it could generate resonance in the function of 'To position main formwork supports', as without adequate props this function could not be executed, even affecting the development of some downstream functions.                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 9  | To position main formwork supports | Although variability is focused directly on fatigue, the function of 'To position main formwork supports' could generate resonance in the system. For example, upstream, the function of 'To open props' could be affected if the positioning of the main formwork supports is incorrect, and if they fall, the quality of the elements could be compromised. Downstream, this function of 'To position main formwork supports' could affect the function of 'To fasten main formwork supports', if it is not carried out adequately, due to forced fastening because of its incorrect position. Similarly, the function of 'To position the ties' could be directly affected, as they are supported by these main formwork supports. Therefore, a proper positioning of the main formwork supports will impact downstream functions such as 'To extend the working platform' and 'To extend main formwork supports', which, although it can be mitigated by leveling the props, would cause imperfections from the first moment of installation, as they are the initial basic elements.         |
| 10 | To fasten main formwork supports   | The function of 'To fasten main formwork supports' could impact upstream the function of 'To position main formwork supports' due to the instability that could be generated by the movements inherent to the activities that must be carried out and condition a new repositioning of the main formwork supports. Downstream, the function of 'To fasten main formwork supports' could alter the function of 'To install props' due to the initial instability of the system, which would probably prevent the execution of the function of 'To define the height of the props'. Therefore, to fasten main formwork supports could guarantee to a certain extent the initial stability and safety required in the system, which will continue to reproduce according to these initial characteristics.                                                                                                                                                                                                                                                                                           |

| No | Functions                         | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11 | To position the ties              | The variability that could be generated in the "To position the ties" function could be essentially due to the placement of the tilting supports on the odd-numbered ties. This omission or alteration of the order of the tilting supports' positioning could directly affect downstream the "To lay boards" function, as the tilting supports will make direct contact with the wooden boards that must be immobilized by nails. In a certain way downstream, if the case warrants it, it could affect the "To position trenches" function, which, although they are not permanently placed, could alter this function. Finally, downstream, if the "To position the ties" function is not performed adequately, it could impede, to the same extent, the execution of the "To extend the working platform" function and the "To extend ties" function. The order of the tilting supports' addition could be corrected, but this would lead to unnecessary reprocessing and the generation of a significant cumulative delay in more than one function. |
| 12 | To define the height of the props | The "To define the height of the props" function must be performed using the system's own elements. Using other elements could impact upstream the "To verify quality" function, which would cast doubt on the performance of this function. Downstream, the "To install props" function could be impacted due to the instability that would be generated in the system using elements foreign to the structure with a variable resistance that could be revealed over time.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 13 | To install props                  | The "To install props" function could generate some variability when working at heights greater than 3.5 m where sturdier and, therefore, heavier shoring is required, which would affect maneuverability due to fatigue. In some sections, reinforcements and additional elements will be required to place inclined shoring, therefore, the repetition of these activities could cause variability upstream in the "To fasten main formwork supports" function, which if repeated impacts occur in the system could generate a certain degree of instability over time. On the other hand, if the placement of these props is not adequate, it would be difficult to continue with the downstream function of "To adjust props" which could only be performed if the props placement has been adequate. On some occasions, more than one prop can be placed continuously to reinforce a specific point.                                                                                                                                                 |
| 14 | To adjust props                   | The adjustment of the props must be performed with the precise number of blows to generate the necessary pressure to stabilize the system. These impacts, if they are abrupt, could generate variability upstream, altering the "To install props" function, since the transmission of movement through the structure could alter the initial location of the shoring. For the same reason, downstream, setbacks could be generated in the "To level the props" function, since the repeated impacts could unlevel the other props that was around, causing rework for its correction.                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 16 | To level the props                | When executing the "To level the props" function, the "To adjust props" function upstream could be affected due to the transmission of movement. The threading in the props is a fundamental characteristic to achieve adequate leveling of the props, however, on some occasions, some lifts would be required. This combination of elements could alter the start of the downstream "To lay boards" function if it falls into an adjust and level props loop.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 18 | To lay boards                     | The "To lay boards" function could generate a downstream variability that would affect the fulfilment of the "To release the formwork for use" function, due to worker fatigue, which would delay the placement of boards and, if there was no timely relief, these boards could fall and be damaged. The same thing would happen if warped boards arrived, which would make it difficult to fix them to the tilting supports.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 22 | To add tilting supports           | The omission or alteration of the order of tilting supports placement could affect the "To position the ties" function, which in turn would downstream affect the "To lay boards" function, as the tilting supports will make direct contact with the wooden boards that must be immobilized by nails. Ultimately, downstream, if the "To position the ties" function is not performed adequately, it could impede, to the same extent, the execution of the "To extend the working platform" and "To extend ties" functions. The order of tilting supports addition could be corrected, but this would lead to unnecessary rework and a significant cumulative delay in multiple functions.                                                                                                                                                                                                                                                                                                                                                              |



| No | Functions                 | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 27 | To cut boards and timbers | The 'To cut boards and timbers' function requires a stationary machine with a circular saw, which must be operated exclusively by certified personnel. Worker concentration must be increased due to the movement of the circular saw to obtain wooden elements with the required dimensions. Incorrect cuts could lead to upstream variability in the 'To move material to be installed' function which, if it were to become recurrent, could affect the 'To check stock' function. Downstream, it would prevent the functions of 'To complete areas'; 'To install boards'; and 'To seal holes', the raw material of which is the product of the cutting machine. This function is of high importance in the system, because if it is not fully completed, the process would end, and the completion of the formwork would not be achieved. |
| 28 | To complete areas         | Difficulties encountered in the 'To complete areas' function could cause variability downstream in the 'To seal holes' function and, in turn, in the 'To install boards' function. Although part of this work could be anticipated, it is recommended to carry it out after the working platform has been completed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 29 | To install boards         | Battens will support lateral loads during the concrete pouring process. Therefore, the appropriate material, the placement of supports, and the relevant reinforcements will allow for the satisfactory containment of the concrete. Variability in the placement of battens has a direct downstream impact on the 'To seal holes' function, which would be generated between the working platform and the battens. If this is not carried out meticulously, the formwork cannot be delivered.                                                                                                                                                                                                                                                                                                                                                |

## Conclusions

The analysis of the system's functional resonance in the formwork of a building slab has allowed us to identify several key functions that could alter other functions around them, both upstream and downstream. For instance, the function of “To position main formwork supports”, which could severely affect the extension of the working platform and the extend main formwork supports. In the case of the function of “To cut boards and timbers”, this impacts the system's safety by introducing a cutting machine that requires a high level of concentration from the operator. Apparently, this function has been highlighted using the Resilience Engineering paradigm. Therefore, FRAM has been able to evidence critical points that could alter the complex socio-technical system of construction, adapting to the realities of the sector to propose improvements in safety management.

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## ERGONOMIA HOSPITALAR E A SEGURANÇA DO PACIENTE HOSPITAL ERGONOMICS AND PATIENT SAFETY

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### Abstract

**Introduction:** Hospital ergonomics addresses the understanding of work in a health system where multiple “actors” (health professionals, patients and family members) interact, therefore it makes a decisive contribution to health organizations and to all those involved. Organizations often care more about patients than about their own workers, forgetting that patients safety also depends on the safety of the person providing healthcare. **Materials and methods:** The present study was carried out in a residential home for the elderly, called Valencia 2. The research consisted of the ergonomic analysis of various patient mobilization tasks performed by health professionals. To this end, the RULA (Rapid Upper Limb Assessment) and REBA (Rapid Entire Body Assessment) assessment methodologies were applied, which are widely used in the identification and analysis of risk postures associated with work tasks. **Results and discussion:** From the application of risk assessment methods, it was concluded that the task “lifting a dependent patient” by one worker presents the highest level of risk compared to the tasks “pushing an armchair with a user” by one worker and “lifting a user of the chair” by two workers.

**Keywords:** ergonomics, hospital ergonomics, ergonomic evaluation.

### Resumo

**Introdução:** A ergonomia hospitalar aborda a compreensão do trabalho num sistema de saúde onde interagem múltiplos “atores” (profissionais de saúde, pacientes e familiares), pelo que desempenha um contributo decisivo para as organizações de saúde e para todos os envolvidos. Muitas vezes as organizações preocupam-se mais com os pacientes do que com os próprios trabalhadores, esquecendo-se que a segurança do paciente depende também da segurança da pessoa que presta os cuidados de saúde. **Materiais e métodos:** O presente estudo foi realizado num lar residencial para idosos, denominada Valência 2. A pesquisa consistiu na análise ergonómica de várias tarefas de mobilização de doentes realizadas pelos profissionais de saúde. Para tal, aplicaram-se as metodologias de avaliação RULA (*Rapid Upper Limb Assessment*) e REBA (*Rapid Entire Body Assessment*), amplamente utilizadas na identificação e análise de posturas de risco associadas a tarefas laborais. **Resultados e discussão:** Da aplicação dos métodos de avaliação de risco concluiu-se que a tarefa “levantar o paciente dependente” por um funcionário apresenta o nível de risco mais elevado comparativamente às tarefas “empurrar o cadeirão com utente” por um funcionário e “levantar utente da cadeira” por dois funcionários.

**Palavras-chave:** ergonomia, ergonomia hospitalar, avaliação ergonómica.

### Introdução

A ergonomia, definida como a ciência que estuda a interação entre o ser humano e os sistemas com os quais trabalha, busca otimizar a relação entre as condições de trabalho e as capacidades e limitações físicas e psicológicas dos trabalhadores, promovendo tanto a segurança quanto a eficiência produtiva (Dul & Weerdmeester, 2008). Em contextos hospitalares, essa disciplina revela-se uma ferramenta essencial para compreender o trabalho num ambiente dinâmico, no qual interagem diversos “atores” - profissionais de saúde, pacientes e familiares - em sistemas complexos e em constante evolução (Serranheira, Sousa & Sousa, 2010). Os três domínios fundamentais da ergonomia são: (i) a ergonomia física, que aborda aspetos como anatomia, antropometria e biomecânica; (ii) a ergonomia cognitiva, que examina processos mentais como perceção, memória e tomada de decisão; e (iii) a ergonomia organizacional, que se concentra na otimização de sistemas sociotécnicos, políticas e fluxos de trabalho (Wilson, 2000). Quando aplicados ao setor hospitalar, esses

domínios possibilitam não apenas a melhoria das condições de trabalho, mas também a prevenção de acidentes, doenças ocupacionais e absenteísmo, promovendo simultaneamente maior eficiência e segurança no atendimento ao paciente (Carayon *et al.*, 2006).

No âmbito hospitalar, a ergonomia, por meio da análise ergonômica do trabalho, fornece informações cruciais para uma compreensão mais aprofundada das atividades laborais. Isso permite uma ação proativa tanto na prevenção de absenteísmo decorrente de incidentes, acidentes e/ou doenças ocupacionais e na melhoria do desempenho organizacional. Consequentemente, contribui para o aumento da produtividade individual e coletiva e para a elevação dos níveis de segurança do paciente.

Entre os principais perigos identificados no ambiente hospitalar, destacam-se:

- Posturas incorretas: trabalhar em posições forçadas ou curvadas, muitas vezes devido à falta de equipamentos ajustáveis, contribui para lesões e desconforto físico;
- Equipamento inadequado: ausência de camas ajustáveis, cadeiras de rodas apropriadas ou elevadores mecânicos aumenta o esforço físico.

As principais lesões musculoesqueléticas associadas ao trabalho de movimentação manual de doentes pelos profissionais de saúde incluem:

- Dores lombares: provocadas pelo levantamento e transferência inadequada de doentes, frequentemente realizadas sem recurso a equipamentos auxiliares;
- Distensões e lesões nos ombros: associadas a movimentos repetitivos e esforços excessivos durante o posicionamento de doentes;
- Lesões nos punhos e mãos: resultantes de movimentos repetitivos, especialmente ao utilizar equipamentos não ergonômicos;
- Problemas no pescoço e na coluna cervical: derivados de posturas forçadas ou prolongadas ao prestar cuidados de proximidade ao doente;
- Lesões nos joelhos: causadas por posições de agachamento ou ajoelamento durante a assistência.

Uma análise ergonômica das tarefas beneficia tanto os trabalhadores, ao reduzir lesões e fadiga, quanto os pacientes, ao melhorar a qualidade e segurança dos cuidados prestados (Carayon & Gurses, 2008). Estudos demonstram que a segurança do paciente está intrinsecamente relacionada à segurança dos profissionais de saúde, evidenciando a importância de uma perspectiva integrada e holística no planejamento de sistemas hospitalares (Pascale Carayon *et al.*, 2014).

Este artigo visa explorar a inter-relação entre a ergonomia hospitalar, a segurança dos pacientes e a segurança dos trabalhadores, destacando como as estratégias ergonômicas podem ser implementadas para equilibrar essas necessidades. Frequentemente, as organizações de saúde priorizam o bem-estar dos pacientes em detrimento dos profissionais, desconsiderando que a segurança e o desempenho destes são elementos cruciais para assegurar a qualidade e segurança dos cuidados prestados.

## **Materiais e Métodos**

O presente estudo foi realizado num lar residencial para idosos, denominada Valência 2. A pesquisa consistiu na análise ergonômica de várias tarefas de mobilização de doentes realizadas pelos profissionais de saúde. Para tal, aplicaram-se as metodologias de avaliação RULA (*Rapid Upper Limb Assessment*) e REBA (*Rapid Entire Body Assessment*), amplamente utilizadas na identificação e análise de posturas de risco associadas a tarefas laborais.

Os profissionais de saúde utilizavam dispositivos de apoio durante as tarefas, como gruas para transferência de pacientes e camas articuladas que permitiam a elevação e ajuste da posição dos pacientes. Essas ferramentas foram consideradas no contexto das avaliações, uma vez que influenciam diretamente a carga biomecânica aplicada durante a execução das tarefas.

Os dados foram recolhidos em situações reais de trabalho, por meio de observação direta e registo fotográfico das posturas adotadas pelos profissionais durante a mobilização de doentes. As posturas foram analisadas

utilizando os critérios estabelecidos pelos métodos RULA e REBA, que permitem pontuar e categorizar o nível de risco ergonómico associado a cada tarefa.

### **Ergonomia Hospitalar na Valência 2**

A ergonomia hospitalar tem como objetivo garantir simultaneamente a segurança, a saúde e o conforto dos profissionais e consequentemente a melhoria da produtividade. Quando bem estudada e implementada, pode ajudar os profissionais de saúde e as organizações de saúde a melhorar a conceção e o design dos equipamentos, os sistemas e os processos de trabalho e permite implementar as necessárias alterações para a prevenção de consequências indesejadas.

A Valência 2, é uma instituição de apoio à terceira idade, onde se verifica que, apesar de existirem equipamentos que permitem auxiliar as tarefas de mobilização dos doentes, estes são obsoletos. Por exemplo, as camas, têm cerca de 20 anos e, como se pode verificar na Figura 1 a altura não é mais adequada para as tarefas a desenvolver, a altura é fixa, pelo que não é possível adaptar a altura das camas às dimensões antropométricas dos profissionais.

Estas camas permitem que a sua parte superior seja elevada, para que o paciente fique mais confortável, no entanto, para tal, a trabalhadora tem de puxar um manípulo para a elevar, como ilustra a Figura 2. Este manípulo está demasiado baixo pelo que a profissional adota uma postura desconfortável.



*Figura 1. Altura inadequada das camas.*



*Figura 2. Operação de elevação da parte superior da cama (rodar o manípulo).*

Alguns pacientes são transportados nuns cadeirões, como se pode ver na Figura 3, que são difíceis de transportar e de manobrar. Estes cadeirões são grandes, pesados e os seus rolamentos não facilitam a sua movimentação (com muitos dos cadeirões possuindo apenas uma separação entre o solo e a base do cadeirão correspondente à altura dos rolamentos).



**Figura 3.** Transporte do paciente num cadeirão.

Durante a execução das tarefas, os funcionários enfrentam constante pressão e uma elevada carga de trabalho, especialmente no turno da manhã. A limpeza e a organização das instalações são realizadas diariamente neste período, o que implica lidar simultaneamente com outras exigências, como prestar cuidados específicos aos utentes, atender telefonemas ou responder às campainhas. Cada dia traz desafios diferentes, e as condições externas às tarefas variam significativamente. Essas condicionantes têm um impacto significativo na ergonomia, pois, para cumprir as expectativas organizacionais e concluir todas as tarefas, os trabalhadores frequentemente negligenciam as posturas que adotam e os métodos utilizados na realização das atividades.

### **Segurança do Paciente**

A segurança do paciente está intimamente relacionada com a segurança dos profissionais de saúde. Quanto maior for o grau de segurança e conforto dos profissionais durante a execução das suas tarefas, maior será o grau de segurança e qualidade dos cuidados prestados ao paciente (World Health Organization [WHO], 2009). Essa relação tem sido amplamente discutida na literatura, que destaca a importância de ambientes seguros tanto para os profissionais quanto para os utentes no âmbito da prevenção de erros e promoção de bem-estar (Vincent *et al.*, 2013).

É imprescindível que os cuidados de saúde sejam prestados com qualidade, de modo a prevenir infeções, evitar lesões, proporcionar conforto e promover o bem-estar do utente (Boyle *et al.*, 2012). Na Valência 2, existe uma preocupação contínua com a segurança e o bem-estar dos pacientes, sendo essa uma prioridade para todos os colaboradores durante a realização das suas tarefas. Essa atenção é positiva e alinhada com as recomendações internacionais sobre boas práticas nos cuidados a populações vulneráveis (The Joint Commission, 2018).

No entanto, mesmo com essa preocupação, nem sempre as tarefas são executadas de maneira que garantam plenamente a segurança e o bem-estar do paciente.

Algumas práticas na Valência 2 podem potenciar o risco de transmissão de doenças aos pacientes. Recorde-se que apesar da realização de exames periódicos, é essencial considerar que os idosos possuem sistemas imunitários comprometidos, sendo extremamente vulneráveis a contaminações (Centers for Disease Control and Prevention [CDC], 2020).

A movimentação e o transporte dos pacientes representam um desafio significativo. Durante essas tarefas, pode ocorrer a exposição dos utentes a lesões, especialmente porque muitas delas são realizadas manualmente. Estudos indicam que o uso inadequado de força manual aumenta o risco de acidentes tanto para o profissional quanto para o paciente (Nelson & Baptiste, 2006). Apesar da disponibilidade de uma grua na Valência 2, ver Figura 4, este equipamento é utilizado apenas em momentos específicos, como pela manhã para levantar os pacientes e à noite para os deitar. Durante o dia, o transporte é frequentemente feito de forma manual, por dois funcionários, sob o argumento de ser mais rápido. Essa prática, no entanto, não está alinhada com as recomendações de boas práticas ergonómicas, que sugerem o uso regular de equipamentos auxiliares para reduzir riscos (ISO/TR 12296:2012).

A implementação de políticas que incentivem o uso consistente de dispositivos de apoio, como gruas e camas articuladas, poderia beneficiar tanto os profissionais quanto os utentes. Estudos mostram que a utilização de tecnologias de apoio não apenas melhora a segurança do paciente, mas também reduz significativamente as lesões musculoesqueléticas entre os profissionais de saúde (Baptiste et al., 2008).



**Figura 4.** Transporte do paciente com grua.

## Resultados

Foram realizadas avaliações ergonómicas a algumas atividades desenvolvidas onde foi possível verificar que existe riscos de lesões músculo esqueléticas para os funcionários e que, portanto, é necessário que sejam tomadas medidas. Na Tabela 1 são definidas prioridades de atuação para as diferentes tarefas.

**Tabela 1.** Quadro resumo das avaliações ergonómicas.

| Tarefa                                          | Método Utilizado | Nível de risco | Interpretação                                                                      |
|-------------------------------------------------|------------------|----------------|------------------------------------------------------------------------------------|
| Levantar paciente dependente<br>(1 funcionário) | REBA             | Nível 3        | Risco alto. Implica ações em breve e reavaliação do risco                          |
| Empurrar cadeirão com utente<br>(1 funcionário) | RULA             | Nível 2        | Risco baixo. Será preciso investigar melhor e poderão ser necessárias modificações |
| Levantar utente da cadeira<br>(2 funcionários)  | REBA             | Nível 2        | Risco baixo. Poderá ser necessário tomar ações de minimização                      |

## Discussão

Para minimizar o risco de lesão musculo esquelética dos profissionais de saúde podem ser disponibilizados equipamentos que contribuem para eliminar ou minimizar o risco, facilitando também a execução das tarefas e aumento do conforto dos pacientes, conforme se apresenta, alguns exemplos na Tabela 2.



Tabela 2. Sugestões de equipamentos.

| Equipamento             | Foto                                                                                | Para que serve?                                                                                     |
|-------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| Disco giratório         |    | Permite, após levantar o paciente, posicioná-lo para o local onde se vai sentar                     |
| Almofada elevatória     |    | Efetua, automaticamente 80% do levantamento do paciente                                             |
| Cadeirão elevatório     |   | Efetua também o levantamento do paciente                                                            |
| Ajudas de transferência |  | Ajuda o paciente a levantar, sendo que não necessário que a trabalhadora exerça algum tipo de força |

Adicionalmente, a formação contínua dos profissionais é uma medida essencial para minimizar os riscos ergonômicos no ambiente de trabalho, particularmente no setor da saúde. A implementação de programas de capacitação que abordem técnicas adequadas de movimentação manual de pacientes, ergonomia e utilização correta de tecnologias assistivas pode reduzir significativamente as lesões musculoesqueléticas e melhorar a segurança geral no ambiente de trabalho.

De acordo com Nelson *et al.* (2006), os programas de formação que ensinam técnicas baseadas em evidências para a movimentação segura de pacientes reduzem significativamente a incidência de dores lombares e outras lesões em profissionais de saúde. Além disso, Loomis *et al.* (2019) reforçam que o treino adequado aumenta a confiança dos trabalhadores na utilização de dispositivos ergonômicos, como elevadores mecânicos, melhorando a adesão às práticas seguras.

A formação deve abranger, técnicas de levantamento seguro, ensinar os profissionais a adotar posturas corretas e usar o peso corporal de forma eficiente, utilização de tecnologias de apoio, capacitar os trabalhadores para operar equipamentos ergonômicos, como camas ajustáveis e elevadores mecânicos, Gestão do tempo e planeamento das tarefas para reduzir a sobrecarga e o stresse associado a turnos intensos, principalmente em horários de maior exigência, como os turnos da manhã.

## Conclusões

A análise ergonômica dos postos de trabalho permite determinar quais são as variáveis existentes, humanas e ambientais.



Para tal, é necessário que nas atividades desenvolvidas pelos profissionais de saúde exista uma relação entre a informação fornecida pela Organização, os meios utilizados em cada situação, os objetivos definidos, os resultados atingidos e a reação do profissional à carga de trabalho.

É fundamental que exista uma intervenção em todos os locais e postos de trabalho, no sentido de minimizar os riscos ergonómicos quer para os profissionais de saúde quer para os utentes e até mesmo para os familiares.

É importante que seja efetuada, na Valência 2, uma reestruturação no local de trabalho no sentido de proporcionar uma maior segurança quer para os utentes quer para os funcionários.

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# CHEMICAL RISK ASSESSMENT METHODS: A COMPREHENSIVE REVIEW AND COMPARATIVE ANALYSIS

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## Abstract

Chemical risk assessment is a process that aims to provide information on the probability of adverse effects following chemical exposures. This paper presents a review of the most widely used chemical risk assessment methods, including COSHH Essentials, Institut National de Recherche et de Sécurité (INRS), Chemical Risk Management (CHARM), Stoffenmanager, ECETOC TRA Targeted Risk Assessment, Advanced REACH Tool (ART), New Approach Methodologies (NAM), Critical Task Exposure Screening (CTES), SQCRA Method, Chem-SAM, UOW, and Chemical Health Risk Assessment (CHRA). A comparative analysis highlights their strengths, limitations, application cases, and use cases is also included. Finally, some recent developments in Artificial Intelligence (AI) applications for chemical risk assessment are included.

**Keywords:** chemical risk, assessment methods, AI applications.

## Introduction

Chemical risk assessment is a critical process for safeguarding occupational, environmental, and public health against potential hazards posed by chemical substances. As chemical risks grow in complexity, the evolution of assessment methodologies and the incorporation of Artificial Intelligence (AI) advancements have become increasingly vital for ensuring effective and modernized safety practices. The methodologies employed for chemical risk assessment vary significantly in complexity, scope, and applicability. This review provides a detailed technical evaluation of the most widely used chemical risk assessment methods, including COSHH Essentials, Institut National de Recherche et de Sécurité (INRS), Chemical Risk Management (CHARM), Stoffenmanager, ECETOC TRA Targeted Risk Assessment, Advanced REACH Tool (ART), New Approach Methodologies (NAM), Critical Task Exposure Screening (CTES), SQCRA Method, Chem-SAM, UOW, and Chemical Health Risk Assessment (CHRA). A comparative analysis highlights their strengths, limitations, application cases, and use cases. Additionally, recent developments in Artificial Intelligence (AI) applications for chemical risk assessment, emphasizing their transformative potential for modern practices, are discussed.

## Overview of Chemical Risk Assessment Methods

A description of the mainly used chemical risk assessment methods is presented next, comprehending each method strengths, limitations, application cases and use cases.

At the end of the chapter, a summary table is presented with the methods covered.

## COSHH Essentials

The Control of Substances Hazardous to Health (COSHH) Essentials, developed by the UK Health and Safety Executive (HSE), is a qualitative and semi-quantitative tool designed to guide employers in managing chemical risks. It categorizes chemicals based on hazard banding and provides control guidance sheets (CGSs) with recommendations for workplace exposure controls.

- Strengths: Simple to use, focuses on practical control measures, low-cost implementation.
- Limitations: Limited to predefined scenarios and lacks precise quantitative exposure assessment.
- Application Cases: Widely used in manufacturing industries, healthcare facilities handling disinfectants, and laboratories with small-scale chemical use.

- Use Cases: Suitable for small to medium-sized enterprises (SMEs) with limited technical expertise. COSHH Essentials aligns well with workplaces requiring straightforward compliance solutions and minimal technical input.

### ***Institut National de Recherche et de Sécurité (INRS)***

INRS offers a suite of methodologies and tools for chemical risk assessment in the French occupational health framework. Tools like SEIRICH are aimed at evaluating workplace exposure and recommending controls.

- Strengths: Tailored for French regulatory requirements, provides detailed workplace-specific assessments.
- Limitations: May lack applicability outside French regulatory contexts, requires technical expertise.
- Application Cases: Industrial workshops, laboratories, and agricultural sectors in France.
- Use Cases: Comprehensive assessment within French industrial and regulatory settings. The INRS methodology is particularly valuable for organizations needing to align closely with French regulations while addressing complex workplace scenarios.

### ***Chemical Risk Management (CHARM)***

CHARM is widely used in offshore industries, particularly in assessing the environmental risks of chemicals discharged into marine environments.

- Strengths: Quantitative and focuses on environmental impact, robust database integration.
- Limitations: Industry-specific (offshore oil and gas), limited applicability to other domains.
- Application Cases: Offshore drilling operations, marine chemical discharge analysis, and environmental impact studies.
- Use Cases: Environmental risk assessment in offshore oil and gas industries. Its focus on marine environments makes CHARM indispensable for compliance and sustainability initiatives in this sector.

### ***Stoffenmanager***

Stoffenmanager is a web-based tool that assesses occupational exposure to hazardous substances and provides risk control advice.

- Strengths: User-friendly interface, incorporates quantitative exposure modeling, widely used across industries.
- Limitations: Relies on default values that may oversimplify complex scenarios.
- Application Cases: Factories handling solvents, automotive industries, and construction sites.
- Use Cases: Occupational exposure assessment in industries with diverse chemical use. Stoffenmanager's integration of AI-based modules enhances its accuracy and adaptability to dynamic workplace conditions.

### ***ECETOC TRA Targeted Risk Assessment***

Developed by the European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC), this tool provides tiered exposure and risk assessment for industrial chemicals.

- Strengths: Tiered approach allows for scalability, well-suited for regulatory compliance under REACH.
- Limitations: Conservative estimates may lead to over-control measures, requires input data accuracy.
- Application Cases: Chemical manufacturing, formulation, and downstream user applications in the EU.
- Use Cases: Risk assessment for regulatory compliance under the European Union's REACH framework. The tool's adaptability makes it ideal for varying levels of regulatory complexity.

### ***Advanced REACH Tool (ART)***

ART is an advanced exposure modeling tool designed to estimate worker exposure to chemicals based on task-specific scenarios.

- Strengths: High accuracy in quantitative exposure estimation, incorporates multiple exposure determinants.
- Limitations: Requires extensive input data, may not be suitable for SMEs.

- Application Cases: Pharmaceutical manufacturing, chemical synthesis facilities, and industrial painting processes.
- Use Cases: Detailed occupational exposure assessment for large-scale industries. ART's precision supports high-stakes environments where exact exposure quantification is critical.

### ***New Approach Methodologies (NAM)***

New Approach Methodologies (NAM) focus on integrating non-animal testing methods and computational modeling to evaluate chemical hazards and exposure scenarios.

- Strengths: Promotes ethical considerations by avoiding animal testing, innovative computational approaches.
- Limitations: Limited validation and adoption, requires specialized knowledge.
- Application Cases: Toxicological risk evaluations in cosmetics, biopharmaceuticals, and agrochemical industries.
- Use Cases: Cutting-edge research and regulatory scenarios requiring alternative approaches. NAM exemplifies the ethical and technological shift in risk assessment paradigms.

### ***Critical Task Exposure Screening (CTES)***

Critical Task Exposure Screening (CTES) is designed to identify and evaluate specific tasks or processes that pose significant chemical exposure risks in workplaces.

- Strengths: Focuses on high-priority tasks, incorporates observational and task-specific data.
- Limitations: Task-specific focus may not cover broader workplace risks, requires detailed task analysis.
- Application Cases: Industrial processes involving volatile solvents, spray painting, and chemical mixing.
- Use Cases: Targeted interventions for high-risk tasks in manufacturing and construction industries. CTES provides actionable insights to mitigate exposure in critical operations.

### ***SQCRA Method***

The Semi-Quantitative Chemical Risk Assessment (SQCRA) method combines qualitative and quantitative elements to evaluate chemical risks in workplaces.

- Strengths: Balances simplicity and detail, applicable to diverse industries.
- Limitations: Limited by the quality of input data, may oversimplify complex risks.
- Application Cases: Small manufacturing units, warehouses storing hazardous materials, and logistics hubs.
- Use Cases: General workplace risk assessment. Its balance of simplicity and detail makes it accessible for varied industrial applications.

### ***Chem-SAM***

Chem-SAM is a comprehensive risk assessment tool that integrates chemical hazard data with exposure scenarios to evaluate workplace safety.

- Strengths: Detailed exposure assessment, customizable for various industries.
- Limitations: Complex implementation, requires substantial data.
- Application Cases: Chemical plants, mining industries, and specialized R&D laboratories.
- Use Cases: High-detail risk assessments for complex workplaces. Chem-SAM excels in environments demanding high precision and flexibility.

### ***UOW Risk Assessment Method***

Developed by the University of Wollongong, this method incorporates both qualitative and quantitative techniques for assessing chemical hazards in academic and research environments.

- Strengths: Specific to academic settings, emphasizes training and awareness.
- Limitations: Limited scalability to industrial applications.
- Application Cases: University laboratories, pilot research facilities, and teaching environments.

- Use Cases: Risk assessment in academic and research laboratories. The UOW method highlights the importance of education and tailored safety practices in research settings.

### **Chemical Health Risk Assessment (CHRA)**

CHRA is a structured approach used primarily in Malaysia for assessing chemical health risks in workplaces.

- Strengths: Highly structured, focuses on compliance with Malaysian occupational health regulations.
- Limitations: Region-specific applicability, limited adoption outside Malaysia.
- Application Cases: Electronics manufacturing plants, oil palm processing facilities, and construction sites.
- Use Cases: Occupational risk assessment in Malaysian industries. CHRA ensures robust compliance with regional regulations, offering a reliable framework for workplace safety.

Table 1 presents a comparison (strengths, limitation and best uses cases) for the above discussed assessment methods.

**Table 1.** Comparative Analysis of Chemical Risk Assessment Methods.

| Method           | Strengths                                    | Limitations                     | Best Use Cases                     |
|------------------|----------------------------------------------|---------------------------------|------------------------------------|
| COSHH Essentials | Simple, practical guidance                   | Limited quantitative capability | SMEs with limited resources        |
| INRS             | Detailed, workplace-specific                 | Region-specific to France       | French industrial settings         |
| CHARM            | Quantitative, environmental focus            | Industry-specific               | Offshore oil and gas               |
| Stoffenmanager   | User-friendly, quantitative modeling         | Oversimplification of scenarios | General industrial use             |
| ECETOC TRA       | Scalable tiered approach                     | Conservative estimates          | REACH compliance                   |
| ART              | High accuracy, task-specific modeling        | Data-intensive                  | Large-scale industries             |
| NAM              | Ethical, innovative computational methods    | Limited validation              | Research and regulatory innovation |
| CTES             | Task-specific focus, actionable insights     | Limited broader applicability   | High-risk task interventions       |
| SQCRA            | Balances simplicity and detail               | Dependent on input data quality | General workplace assessments      |
| Chem-SAM         | Comprehensive exposure assessment            | Complex implementation          | High-detail workplace assessments  |
| UOW              | Academic focus, tailored training            | Limited industrial scalability  | Academic and research labs         |
| CHRA             | Structured, regulatory compliance (Malaysia) | Region-specific                 | Malaysian workplace settings       |

### **Recent Developments in AI for Chemical Risk Assessment Methods**

The integration of Artificial Intelligence (AI) into chemical risk assessment has emerged as a transformative approach to enhance accuracy, efficiency, and scalability. AI-driven models leverage large datasets such as those from regulatory databases (e.g., REACH, OSHA) and toxicological repositories (e.g., ToxCast) alongside advanced algorithms, including random forests, neural networks, and support vector machines, to predict chemical hazards, exposure levels, and control measures with unprecedented precision. Key developments include:

- Machine Learning for Exposure Prediction: Algorithms trained on historical exposure data can predict potential exposure scenarios based on task, substance, and workplace conditions. AI-based tools such as advanced Stoffenmanager modules now incorporate machine learning to refine exposure modeling.
- Natural Language Processing (NLP) for Data Mining: NLP algorithms extract relevant hazard and exposure data from regulatory documents, research papers, and safety data sheets, automating data input and reducing manual errors.
- AI-Powered Risk Ranking Systems: Tools like ChemAI integrate risk ranking algorithms to prioritize high-risk substances, enabling targeted control interventions.
- Digital Twins for Scenario Testing: Digital twin technology, paired with AI, allows the creation of virtual workplace models to simulate chemical exposure under varying conditions, offering real-time feedback for risk mitigation strategies. For instance, simulations in large-scale manufacturing plants demonstrate reduced implementation costs and improved safety outcomes.
- AI in Toxicology: Predictive toxicology models powered by AI evaluate potential health risks of new chemicals, reducing reliance on animal testing and expediting regulatory approval processes.
- Cloud-Based AI Platforms: Platforms like RAMP (Risk Assessment Modeling Platform) use cloud computing and AI to centralize chemical risk assessment, enabling collaborative and remote evaluations across global sites.

#### ***Examples of AI Applications in Chemical Risk Assessment***

- Stoffenmanager AI Modules: Recent updates in Stoffenmanager leverage AI to predict workplace exposure with greater accuracy, integrating historical data and real-time inputs to model risk scenarios dynamically.
- ChemAI: This tool uses AI algorithms for prioritizing chemical risks, combining hazard data, exposure potential, and workplace practices to rank substances by risk level.
- ToxCast and Tox21 Programs: These U.S. Environmental Protection Agency (EPA) initiatives employ machine learning to predict toxicological endpoints based on chemical structure and activity data.
- AI-Driven Digital Twins: In collaboration with industrial partners, digital twin models simulate complex environments, such as large-scale manufacturing plants, to test chemical exposure mitigation strategies before implementation.
- RiskMap AI: A cloud-based tool that integrates AI for real-time monitoring of chemical hazards and provides actionable recommendations for workplace safety improvements.

#### ***Application Cases for AI in Chemical Risk Assessment***

- Healthcare: AI models are used to predict exposure to disinfectants and develop optimized ventilation strategies in hospitals.
- Manufacturing: Automated assessment of solvent risks in production lines, identifying areas for improved containment.
- Construction: AI-driven analysis of silica dust exposure to implement real-time monitoring and control.
- Regulatory Compliance: AI tools assist in generating tailored compliance reports for REACH, OSHA, and other frameworks.

#### **Conclusion**

The choice of a chemical risk assessment method depends on the specific context, regulatory requirements, and available resources. While COSHH Essentials and Stoffenmanager offer accessible solutions for general workplaces, advanced tools like ART and Chem-SAM are better suited for detailed quantitative assessments. Regional tools such as INRS and CHRA provide tailored solutions within their regulatory frameworks, whereas innovative approaches like NAM and CTES represent the future of chemical risk assessment by integrating ethical and computational advancements. Moreover, the advent of AI-driven tools is revolutionizing the field,



enabling more precise, efficient, and adaptable risk assessments. Understanding the strengths and limitations of each method is crucial for selecting the most appropriate approach for effective chemical risk management.

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# APOIO PSICOSSOCIAL COMO ARMA FUNDAMENTAL DO MÉDICO NA REINTEGRAÇÃO LABORAL: RELATO CASO

## PSYCHOSOCIAL SUPPORT AS A FUNDAMENTAL TOOL FOR PHYSICIANS IN WORKPLACE REINTEGRATION: CASE REPORT

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### Abstract

**Introduction:** Mental health among healthcare professionals (HPs) is a growing challenge. Excessive stress and burnout can lead to inappropriate behaviors, compromising the well-being of both workers and patients. This case report describes the intervention in a neurology nurse experiencing workplace aggression episodes related to occupational stress and personal issues. **Objective:** To demonstrate the importance of early intervention and psychosocial rehabilitation measures for workplace reintegration in cases of occupational stress. **Methods:** This is a case report of a male nurse evaluated by Occupational Health due to aggressive behaviors. He reported significant stress linked to his mother's cognitive decline from advanced Alzheimer's disease. A conditional fitness certificate was issued, recommending reduced extra shifts and psychological support. After a subsequent aggression complaint, he was diagnosed with major depression and temporarily deemed unfit for direct patient contact. Following adherence to the therapeutic plan, he was reintegrated into the Imaging Department, reducing exposure to occupational stressors. **Conclusion:** This case highlights the importance of a multidisciplinary and preventive approach in managing occupational stress. Interventions such as psychological support, workload reduction, and functional realignment were critical for successful workplace reintegration, ensuring safety and quality in the work environment.

**Keywords:** Workplace reintegration; Occupational stress; Aggression; Psychosocial risk.

### Resumo

**Introdução:** A saúde mental dos profissionais de saúde (PS) é um desafio crescente. O stress excessivo e o burnout podem desencadear comportamentos inadequados, comprometendo o bem-estar de trabalhadores e pacientes. Este relato descreve a intervenção em um enfermeiro de Neurologia com episódios de agressão no trabalho, relacionados ao stress ocupacional e problemas pessoais. **Objetivo:** Demonstrar a importância da intervenção precoce e medidas de reabilitação psicossocial para a reintegração laboral em casos de stress ocupacional. **Metodologia:** Relato de caso de enfermeiro, sexo masculino, avaliado por Medicina do Trabalho por comportamentos agressivos. Referia stress significativo devido a agravamento do estado cognitivo de mãe com Alzheimer. Foi emitida ficha de aptidão condicionada, recomendando a redução de turnos extra e acompanhamento psicológico. Após nova queixa de agressão, foi diagnosticado com depressão major com seguimento em Psiquiatria, com inaptidão temporária para contacto direto com pacientes. Após adesão ao plano terapêutico, foi reintegrado no serviço de Imagiologia, minimizando fatores de stress ocupacional. **Conclusão:** Este caso reforça a importância de uma abordagem multidisciplinar e preventiva na gestão do stress ocupacional. Medidas como apoio psicológico, redução de carga laboral e realocação funcional foram essenciais para a reintegração laboral, garantindo segurança e qualidade no trabalho.

**Palavras-chave:** Reintegração laboral; Stress ocupacional; Violência Laboral; Risco psicossocial.

### Introdução

A violência no ambiente laboral é uma problemática crescente, particularmente no setor da saúde, onde os profissionais estão frequentemente expostos a agressões físicas e verbais. De acordo com a Organização Mundial da Saúde (OMS), a incidência de violência contra trabalhadores da saúde aumentou significativamente nos últimos anos, constituindo um dos principais fatores que contribuem para a exaustão profissional e para o

abandono da carreira (WHO, 2023). Dados globais revelam que 22,8% dos trabalhadores já experienciaram violência ou assédio no contexto laboral, sendo a prevalência superior entre as mulheres. No setor da saúde, essa problemática é ainda mais preocupante, representando 73% dos acidentes de trabalho não fatais em serviços como Psiquiatria e Serviço de Urgência (Murcho *et al.*, 2024).

A violência no local de trabalho é reconhecida como um fator de risco relevante para o agravamento do stress e do burnout entre os profissionais de saúde. As repercussões incluem perturbações no bem-estar emocional, tais como irritabilidade, insónias, frustração e fadiga crónica. Estas condições podem precipitar o desenvolvimento de burnout e quadros depressivos, comprometendo a qualidade do desempenho profissional (OIT, 2020). Um estudo realizado em 2011, divulgado pela Academia Americana de Cirurgias Ortopédicas, demonstrou que 87% de mais de 2.000 médicos nos Estados Unidos reportaram sentir níveis elevados de stress e burnout durante um dia normal de trabalho (Alan H. Rosenstein, 2012). Em Portugal, estudos conduzidos entre 2011 e 2013 revelaram que 21,6% dos profissionais de saúde apresentavam níveis moderados de burnout, enquanto 47,8% evidenciavam níveis elevados (Marôco *et al.*, 2016). De forma ainda mais preocupante, 86% dos enfermeiros referiram trabalhar sob níveis elevados ou moderados de stress, valores superiores aos registados na população geral (Gomes *et al.*, 2016).

Estudos mais recentes reforçam a gravidade desta situação. Um estudo publicado na JAMA Network Open, 2023, indicou que aproximadamente 60% dos profissionais de saúde relataram sintomas moderados a graves de burnout após a pandemia de COVID-19, um aumento expressivo face a estudos prévios, destacando-se como um fator crítico que compromete não só a segurança, mas também a qualidade dos cuidados prestados aos pacientes. Além disso, evidências sugerem que profissionais de saúde que experienciam *burnout* apresentam um risco 2,5 vezes superior de cometer erros clínicos, aumentando a probabilidade de eventos adversos na prática assistencial (The Lancet Public Health, 2021).

Para além dos impactos na saúde dos profissionais, o *burnout* e o stress ocupacional podem desencadear comportamentos disfuncionais, incluindo episódios de agressividade verbal ou não verbal dirigidos a colegas e pacientes (Zisook S. *et al.*, 2022). Embora a literatura científica tenha explorado amplamente a violência dirigida contra os profissionais de saúde (ARS, 2019), existe uma lacuna significativa no estudo das estratégias para gerir e intervir nos casos em que os próprios profissionais manifestam comportamentos agressivos. Esta insuficiência de estudos evidencia a necessidade de aprofundar a investigação sobre estratégias eficazes de identificação, prevenção e intervenção, garantindo um ambiente clínico seguro e saudável para todos os envolvidos.

Neste contexto, o presente estudo de caso visa ilustrar a importância da intervenção precoce e das medidas de reabilitação psicossocial na reintegração laboral de profissionais de saúde em situações de stress ocupacional, apresentando um caso clínico específico. A partir da premissa de que o apoio psicológico e psiquiátrico, aliado a medidas preventivas, como a redução de turnos extra, desempenha um papel fundamental na mitigação destes riscos, propõe-se que o Serviço de Medicina do Trabalho tenha um papel central na implementação de programas adaptados às necessidades individuais dos trabalhadores. Estas iniciativas podem assegurar processos eficazes de reintegração laboral, promovendo um ambiente profissional mais saudável e seguro.

## Metodologia

O presente relato de caso descreve a avaliação e acompanhamento de um enfermeiro do serviço de Neurologia, conduzidos pelo Serviço de Medicina do Trabalho. A metodologia adotada baseou-se na recolha e análise de múltiplas fontes de informação, de forma a assegurar uma abordagem abrangente e detalhada do caso.

Inicialmente, foram realizadas entrevistas estruturadas com o profissional, permitindo uma avaliação pormenorizada da sua condição psicológica e ocupacional. Este processo possibilitou a identificação dos principais fatores de stress associados à sua prática clínica, bem como a compreensão do impacto da sua vivência pessoal na sua estabilidade emocional e comportamental no contexto laboral.

Além disso, foram analisados os registos clínicos provenientes dos Serviços de Medicina do Trabalho, Psicologia e Psiquiatria, proporcionando uma visão integrada da evolução clínica do trabalhador e das

intervenções terapêuticas realizadas. Paralelamente, foi efetuada uma avaliação funcional do profissional e das suas condições laborais, permitindo a identificação de fatores de risco psicossociais que poderiam comprometer a sua capacidade de desempenho e adaptação ao ambiente de trabalho.

As intervenções propostas foram fundamentadas em diretrizes internacionais para a gestão do *burnout* e do stress ocupacional, garantindo uma abordagem baseada na melhor evidência disponível. A estratégia terapêutica incluiu recomendações para a redução de carga horária excessiva, apoio psicológico e psiquiátrico e realocação funcional para um setor com menor exposição a fatores desencadeantes de stress.

Por fim, foi implementado um processo de monitorização contínua da adesão ao plano terapêutico, bem como da evolução do profissional no seu processo de reintegração laboral. Acompanhamentos periódicos foram realizados para avaliar o impacto das medidas adotadas na sua estabilidade emocional e desempenho profissional, garantindo um acompanhamento estruturado e individualizado ao longo do tempo.

## **Relato de caso**

### Antecedentes:

Enfermeiro, sexo masculino, de 43 anos, com carga horária semanal de 40 horas em regime de turnos (diurno e noturno), com jornadas de 12 horas consecutivas. Exerceu funções no serviço de Neurologia de um hospital periférico após o diagnóstico de Alzheimer da mãe em estágio avançado, motivado pelo interesse em compreender melhor esta patologia. Este contexto, associado ao agravamento do estado cognitivo da mãe no último ano, gerou uma elevada sobrecarga emocional, afetando a gestão do stress entre a vida pessoal e laboral.

### Intervenção Inicial:

Em julho de 2023, o enfermeiro foi avaliado em Exame de Saúde Ocasional, solicitado pela chefia, após múltiplas queixas de comportamentos agressivos verbais e irritabilidade reportados por colegas. Identificou-se uma relação direta entre a sobrecarga emocional e a natureza exigente das funções no serviço de Neurologia, que envolve contacto próximo e prolongado com doentes dependentes e em estado crítico.

Foi emitida ficha de aptidão com aptidão condicionada, recomendando a cessação de turnos extra, acompanhamento por Psicologia Ocupacional e a manutenção de carga horária padrão para reduzir o risco de *burnout* e minimizar o stress ocupacional.

### Evolução Clínica:

Em outubro de 2023, foi realizada nova avaliação após queixa formal de agressão física a um doente, por parte de um elemento da sua equipa. O enfermeiro negou o episódio, mas relatou perda parcial de memória do evento. Foi encaminhado para consulta de Psiquiatria, onde foi diagnosticado com depressão major e iniciada terapêutica com psicofármacos. Diante deste diagnóstico, foi emitida ficha de aptidão com inaptidão temporária, com recomendações para evicção de qualquer tarefa com contacto direto com doentes e obrigatoriedade de seguimento psicológico e psiquiátrico. O profissional foi informado de que a não adesão ao plano estabelecido resultaria em inaptidão definitiva para o exercício das suas funções.

### Reintegração Laboral:

Em fevereiro de 2024, após adesão total ao plano terapêutico e evolução clínica favorável, foi realizada a reintegração laboral. Para minimizar fatores de stress ocupacional, o profissional foi realocado para o serviço de Imagiologia, um ambiente com menor contacto direto e prolongado com doentes dependentes ou em estado crítico. Essa mudança permitiu reduzir a exposição a situações emocionalmente desgastantes, como internamentos prolongados, comuns na Neurologia. Além disso, manteve-se o acompanhamento pela Medicina do Trabalho e Psicologia Ocupacional, com avaliações regulares para monitorizar o estado de saúde mental e a adaptação às novas funções.

## **Discussão**

O caso apresentado reforça a importância do stress ocupacional e do *burnout* como fatores determinantes para a saúde mental dos profissionais de saúde. A exposição contínua a ambientes laborais exigentes não só impacta negativamente a saúde dos trabalhadores, mas também compromete a qualidade dos cuidados

prestados, afetando colegas e pacientes (World Health Organization [WHO], 2023). A elevada prevalência de *burnout* no setor da saúde, superior à da população em geral, reforça a necessidade de implementar estratégias de intervenção eficazes e preventivas para mitigar os seus efeitos (Marôco *et al.*, 2016; Gomes, Faria & Lopes, 2016).

A intervenção precoce e o acompanhamento multidisciplinar foram fundamentais para a gestão do caso descrito. O diagnóstico rápido de depressão major e a implementação de um plano terapêutico individualizado foram essenciais para minimizar o impacto dos comportamentos inadequados e garantir um ambiente de trabalho seguro. A literatura aponta que o suporte psicológico e psiquiátrico, aliado a medidas organizacionais, como a redução de carga horária e a realocação funcional, são fatores determinantes na recuperação e reintegração laboral de profissionais com *burnout* (Maslach & Leiter, 2016; Salvagioni *et al.*, 2017).

Apesar da escassez de relatos de caso diretamente comparáveis, estudos corroboram a associação entre *burnout* e o aumento da agressividade no ambiente laboral. Profissionais de saúde submetidos a níveis elevados de stress ocupacional apresentam maior propensão para desenvolver sintomas emocionais que podem afetar negativamente a dinâmica do local de trabalho (La Torre, G *et al.*, 2022). Além disso, a literatura sugere que a adoção de estratégias como apoio psicológico contínuo e monitorização da adaptação ao trabalho pode atenuar os impactos do *burnout* e prevenir comportamentos inadequados (Havaei *et al.*, 2019).

Neste caso, a realocação do enfermeiro para o serviço de Imagiologia demonstrou-se uma abordagem eficaz para reduzir a exposição a fatores de stress ocupacional, em conformidade com estudos que defendem a necessidade de adaptar as funções laborais às condições emocionais e clínicas dos trabalhadores (Aronsson *et al.*, 2017). Esta medida está alinhada com as recomendações da literatura, que enfatiza que a reintegração gradual e o acompanhamento contínuo por equipas de saúde ocupacional são essenciais para garantir um ambiente de trabalho seguro e saudável (Hakanen & Schaufeli, 2012; Halbesleben *et al.*, 2014).

O relato de caso expõe lacunas na gestão institucional de situações de agressividade por parte de profissionais de saúde. Embora existam amplos estudos sobre violência contra estes profissionais (Gacki-Smith *et al.*, 2009; Arnetz *et al.*, 2015), a literatura sobre a abordagem e reabilitação de profissionais que manifestam comportamentos agressivos permanece escassa. O desenvolvimento de políticas institucionais específicas e programas preventivos pode representar uma solução viável para reduzir a incidência e os impactos dessas situações (Esteves, G. G. L *et al.*, 2019; Jarruche, L. T., *et al.*, 2021).

Este caso sublinha a importância da Medicina do Trabalho na identificação precoce de fatores de risco psicossociais e na implementação de estratégias de acompanhamento e reintegração. A atuação integrada da Medicina do Trabalho não só proporciona ajustes funcionais e acompanhamento terapêutico contínuo, mas também promove um ambiente organizacional mais saudável e seguro, reduzindo a reincidência de comportamentos inadequados. Portanto, é essencial que as instituições desenvolvam programas de saúde ocupacional que incluam protocolos claros de intervenção precoce, suporte psicossocial e estratégias que promovam o bem-estar mental dos profissionais.

### Limitações do estudo

O presente estudo apresenta algumas limitações que devem ser consideradas na interpretação dos seus achados. Em primeiro lugar, trata-se de um relato de caso único, o que restringe a possibilidade de generalização das conclusões para outras populações ou contextos laborais. O caráter individual e circunstancial do caso limita a extrapolação dos resultados para um espectro mais amplo de profissionais da saúde.

Além disso, a recolha de dados foi baseada essencialmente em fontes secundárias e no relato subjetivo do profissional, o que pode introduzir vieses de memória e interpretação. A ausência de instrumentos padronizados e validados para a avaliação do impacto das intervenções implementadas, como escalas específicas para medir os níveis de stress, *burnout* e agressividade, representa uma limitação metodológica adicional. A utilização de métricas objetivas poderia fortalecer a análise dos efeitos das estratégias adotadas.

Outra limitação relevante reside na falta de comparação com outros casos clínicos semelhantes. Embora a literatura científica forneça suporte teórico para a associação entre *burnout*, agressividade e estratégias de

intervenção, a inexistência de um grupo de controle ou de múltiplos relatos de caso compromete a avaliação da efetividade das medidas aplicadas.

Por fim, investigações futuras poderão beneficiar de um desenho metodológico mais abrangente, incluindo uma amostra mais extensa de profissionais que vivenciem situações semelhantes. Estudos longitudinais e controlados poderão permitir uma análise mais robusta da eficácia das estratégias de reintegração laboral e do impacto a longo prazo das intervenções psicossociais implementadas.

## Conclusão

Este caso destaca a importância da intervenção precoce e personalizada na gestão de situações de *burnout* e stress ocupacional, evidenciando a relevância de medidas como a redução da carga laboral, o apoio psicológico e psiquiátrico e a adaptação das condições laborais. A realocação para o serviço de Imagiologia, aliada ao acompanhamento contínuo, foi essencial para a recuperação do profissional e para a sua reintegração em um ambiente seguro e saudável. Este relato reforça a necessidade de desenvolver políticas institucionais que promovam programas de reabilitação psicossocial adaptados às necessidades individuais dos profissionais de saúde.

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# COMPETENCY-BASED HUMAN RESOURCE MANAGEMENT (CBHRM) METHODS IN OCCUPATIONAL SAFETY AND HEALTH: REVIEW, APPLICATIONS, AND CONTRIBUTION

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## Abstract

A comprehensive review of the existing literature revealed multiple definitions of CBHRM, leading to confusion in the description of CBHRM practices and their implementation in the workplace. This study aims to clearly understand the essential characteristics of competency-based human resource management (CBHRM) in the workplace and its causes and effects. This study conducted a systematic literature review using different databases, focusing on English-language articles published between 2018 and 2024. The defining features of CBHRM in OHS include recruitment and selection, training and development, performance appraisal, reward system, and career planning. CBHRM practices in the workplace include organizational factors, individual factors, and human resources. CBHRM outcomes in the workplace include employee, organizational, and financial outcomes. This study contributes to a comprehensive understanding of CBHRM in the workplace that benefits HR managers.

**Keywords:** competence, human resource management, literature review, Occupational Health.

## Introduction

Human resources play an essential role in determining the success or failure of an organization. Effective management of human resources is essential for the survival and progress of the organization. The quality of the organization's human resources largely determines the success of its operational processes (1). To enhance employee performance, organizations need human resources with unique skills and abilities aligned with the organization's vision and mission. Therefore, setting work standards as a reference point is essential to compare actual performance with expected results (2).

Competence is the ability to effectively perform a task or task based on the necessary skills, knowledge, and work attitude. Assessing the level of competence is essential to understand the degree of success expected, whether it falls into the "good" or "average" category. Required competencies serve as a basis for evaluating job performance. With their unique characteristics, human resources need continuous development of their competencies. The competence of human resources is of great importance because it represents human capital and acts as an active factor in the organization's development. In addition, the competence of human resources is a critical factor in effectively managing organizational resources (3).

Competency-based human resource management (CBHRM) is considered a critical strategy to ensure proper recruitment and development of employees. It is widely recognized as an essential component in various organizations. CBHRM establishes a strong link between employees' competence and organizations' overall success (4, 5).

Since the 1990s, Competence-Based Human Resource Management (CBHRM) has been integrated into human resource management (6). It adopts a competency-based approach in various HRM practices, including recruitment and selection, training and development, and performance appraisal and compensation. Unlike traditional HRM, which focuses on job activities, CBHRM emphasizes individuals and their knowledge, skills, and attitudes. By incorporating competencies into the framework, CBHRM enhances organizational productivity by identifying the critical distinctions between exemplary and average performers and subsequently working towards closing those gaps (7).



CBHRM serves as the basic framework in organizations to guarantee accurate human resource planning. It aims to ensure sufficient competent employees to meet organizational needs (8). In addition, CBHRM is recognized for its effectiveness in empowering line managers to achieve desired results and motivating all employees to increase competence. It serves as the cornerstone of effective workforce management (8).

Despite the critical role CBHRM plays in organizations, there is considerable confusion surrounding its definition and implementation. There is no consensus on the nature of CBHRM and how it should be effectively practiced (9). The present study investigated competency-based human resource management in workplaces. The primary purpose of this study was to investigate the characteristics, advantages, and disadvantages of CBHRM used in OHS. In particular, the fields and industries in which these techniques are used have also been examined.

## **Methods**

The present study, as a literature review, was conducted in 2024 to combine articles that provide important insights to OHS researchers the articles from 2018 up to now were reviewed. The review of the papers was done according to the PRISMA checklist. A systematic electronic search was done in PubMed, Science Direct, Scopus, and PLOS ONE. The collection of articles from databases was done using proper research keywords “human resource management,” “competence,” “competence management,” “competency-based management,” and “competency-based human resource management”). Only organizational and industrial literature was considered for data collection in this study. The keyword search encompassed paper titles and abstracts, resulting in significant irrelevant material. To address this issue, the search was narrowed down to titles only. The inclusion criteria consisted of studies written in full-text English that examined the measurement of CBHRM, its determinants, and/or predictors. Both qualitative and quantitative studies were eligible for inclusion.

## **Screening**

We explored the articles' titles, abstracts, and keywords. At this step, irrelevant and non-English articles, books, journals, conference articles, and unpublished articles were excluded. The articles were classified based on PRISMA on an Excel sheet using the following dimensions:

- Authors
- Year of publication
- Title of article
- Country
- Field of study
- Type of organization
- Research questions/objectives
- CBHRM model
- Variables
- Instrument
- Main findings
- Limitations

In the second phase, the articles were categorized based on the CBHRM application model and their related fields. Subsequently, the analysis of the articles included an examination of the statistical results of the applied field and the evaluation of the distribution of articles. Any study that has not measured human resource management, predecessors, or consequences was removed from the analysis. Figure 1 shows the research method used in this study.

## Results

### Search Results

Using the search strategy, the initial search identified 472 potential articles from the databases between 2019 and 2024. After identification and screening, 439 articles were removed because of date, document type, source type, language, and off-topic, and 25 articles were included in the study.

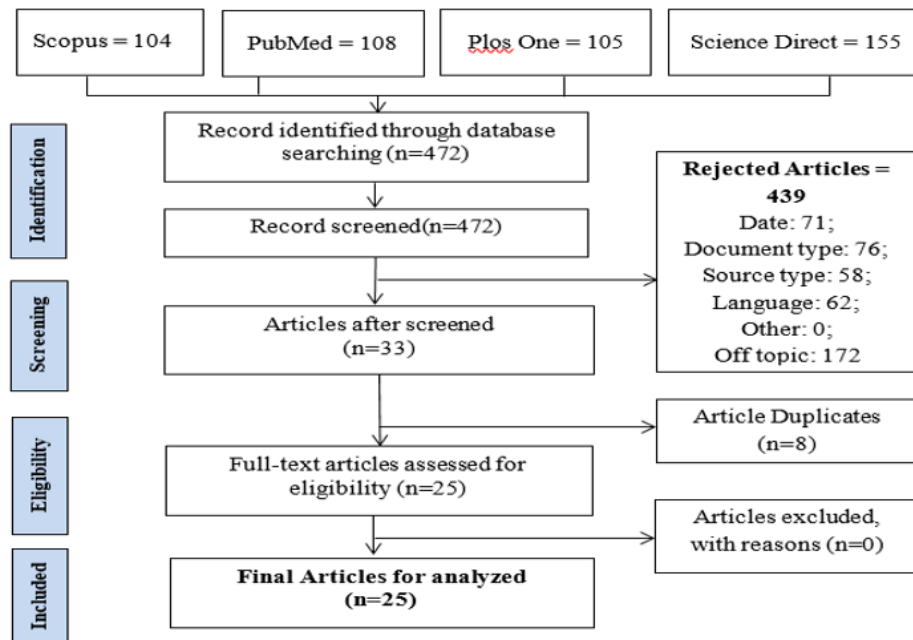


Figure 1. PRISMA Flow Diagram

### Analytical Findings

The following is a review of essential definitions and concepts for Competency-based Human Resource Management in the work environments discussed in various studies.

#### Definition of Competence

As the literature has been identified, the definition of competence differs between the US and British approaches. In the US approach, "competence" is a person's essential behavioral characteristics that help superior performance (10, 11). On the other hand, the British approach defines "competence" as the ability to perform activities in a particular job (12). These two approaches are complementary and have led to a multidimensional understanding of individual-level competencies by the late 1990s (13). The interpretation of the concept of competence depends on the viewer's perspective (6). However, for this study, competence refers to interconnected knowledge, skills, and attitudes that are shown as behavior and enable individuals to perform their duties effectively in the organization (14, 15).

Competence refers to the essential characteristics of behavior, including the motivations, personal characteristics, self-concept, values, knowledge, and skills of people who show superior performance, as Otoo (16). As mentioned by Tarigan & Setiawan, it is related to what people can do, not what they may potentially do (17).

#### Definition of Human Resource Management

The term "human resources" refers to the individuals within an organization, as explained by Boon et al. (18). When managers have human resource responsibilities, they aim to facilitate individual help to achieve organizational goals, as Mitchell et al. (19). The importance of human resource efforts stems from the fact that humans have a constant presence in every organization. They set goals and seek innovation to achieve

organizational goals and purposes. According to Wright and Ulrich (2017), human resource management is an area of public management that covers various aspects of planning, organizing, implementing, and controlling processes in production, marketing, finance, and employees (20). Human resources play a growing vital role in achieving the company's goals, which leads to the regular collection of various human resource research experiences and findings known as management (21). Human Resource Management includes a set of knowledge on how effective human resources are managed.

### **Definition of Competence-Based Human Resource Management (CBHRM)**

Gunawan et al. emphasized that workforce quality significantly affects an organization's success (22). As highlighted by Tarigan & Setiawan, human resource management is essential in organizations (17). It goes beyond administrative tasks to focus on developing the potential of human resources for nurturing creativity and innovation. As Otoo pointed out, proper human resources are essential for organizations to provide exceptional and valuable services (16). According to Tarigan & Setiawan, each member's order and commitment are critical to achieving productivity (17).

Literature shows many definitions of the concept of CBHRM. However, CBHRM can be understood as applying HRM practices, which connect a competence model to the competencies needed to perform job roles in an organization. This reflects the change in the traditional human resource management approach, which primarily relies on job descriptions and task analysis, towards a more individual-centered approach that emphasizes people (23). CBHRM adopts a view that aligns employees' goals and behaviors with organizational goals. This model recognizes that employees' needs may vary in different organizations and affect their perception and evaluation of HRM practices (6).

### **Dimensions**

The literature review reveals various dimensions of CBHRM, as outlined in Table 1. In this study, we compared and analyzed the terms across these dimensions and their respective underlying meanings. The dimensions of CBHRM were categorized into five distinct attributes, namely (1) recruitment and selection, (2) training and development, (3) reward system, (4) performance appraisal, and (5) career planning.

### **Recruitment and Selection**

Recruitment and selection include procedures to attract people with appropriate competence conditions for requesting intra-organizational posts and choosing the most appropriate candidate for a specific role and organization (5). Competence acts as a basis for comparing the capabilities of the servants. However, it is essential to note that the recruitment and selection processes are different for the managers and staff (24). When selecting candidates for linear manager posts, senior executives and human resources professionals must first clarify the effective employees in the organization and use competence models to ensure that the right people are in the correct position (6). This process may include bureaucratic procedures that can add to the complex process (25). On the other hand, bureaucratic procedures may not be involved when hiring and selecting personnel. The recruitment process can be relatively simple if the servants show their knowledge, skills, and attitudes (26).

Traditional HR management identifies people who meet the requirements specified in the job description. The candidate's educational background, work experience, and other relevant qualifications are assumed to demonstrate the candidate's ability to perform the assigned job duties successfully (27). Competency-based HRM evaluates the applicant's decision-making process by evaluating their demonstrated skill in performing job-related tasks. It compares the applicant's skills and talents to competency models that identify the characteristics of highly successful or exemplary performers in their specific work areas (27).

## **Training and Development**

Training and development involves improving the skills, knowledge, and attitudes required for specific job roles in an organization. This is critical for organizations striving for improvement (23, 28). A competency-based education and development system focuses on developing employees' competencies to enhance their performance in their respective roles. The system also includes a self-reflection process for personal development among personnel (14). As a result, HR can develop programs that align with the future needs and demands of the workplace. In traditional HR management, the process is either vague or ambiguous. Competency-based HRM develops individual competencies to achieve exemplary performance and adapt to change (27).

## **Reward System**

The reward system is designed to motivate and encourage employees to increase their performance. This is an essential strategy to ensure practical work and fair recognition of diligent efforts (29). The system is designed to provide rewards based on an employee's merit in the workplace rather than on position or job title. Human resource managers are essential in creating, administering, and efficiently distributing the reward scheme (5). Rewards may include salary, incentives, bonuses, health insurance, job security, bonuses, coupons, and other similar benefits (24, 30). In addition, the attractiveness of the reward plan is a factor that can attract new talents to the organization (31) and is also the primary motivation for people to apply for specific job positions. The more attractive the reward scheme, the more likely the number of applicants will increase (32). Work analysis and job descriptions are crucial in traditional HR management as they are fundamental elements. They are the building blocks for various HR activities such as recruitment, selection, orientation, training, rewards, performance evaluations, and personnel development (27). In Competency-based HRM, competencies are the characteristics and skills people use to achieve successful and outstanding performance. These competencies are the basic principles or the basis of human resources activities (27).

## **Performance Appraisal**

Performance appraisal, also known as performance review and appraisal (33), is the systematic process of evaluating various aspects of an employee's job, including their attributes, characteristics, performance, related behavior, and outcomes. This evaluation process aims to provide feedback to enhance competency and performance. Using a competency-based performance appraisal, there is a shared understanding of the criteria that will be assessed (6, 32). In traditional HR management, the goal is to minimize costs while providing performance feedback to people. This includes deciding on salary increases, promotions, and other related matters (27). In competency-based HRM, people are evaluated based on competency frameworks matching their job responsibilities. They receive constructive feedback that helps them improve towards achieving exemplary performance (27).

## **Career Planning**

Career planning includes making informed decisions about one's career path, charting career growth paths, and taking actions to promote personal and professional development. Sometimes, career planning is also known as succession planning. The distinction between career planning and succession planning is that career planning helps employees identify and acquire necessary competencies for future development based on competency analysis (34, 35). This system enables employees to assess needed competencies, compare them to their existing competencies, and identify potential positions that align with their future career aspirations (36-38). On the other hand, succession planning is a process in which organizations focus on key positions that are expected to become vacant and prepare for a smooth transition to the next generation of leaders in those positions. The organization may groom the right candidate and provide them with support and growth opportunities. Alternatively, the organization may hire specifically for a temporary position to promote the individual to the desired position.

**Table 1.** A summary of reviewed articles

| Row | Authors<br>(year)                            | Title                                                                                                                                           | Country        | Field of Industry             | Dimensions of CBHRM       |                          |               |                       |                 | Instrument                 |
|-----|----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-------------------------------|---------------------------|--------------------------|---------------|-----------------------|-----------------|----------------------------|
|     |                                              |                                                                                                                                                 |                |                               | Recruitment And Selection | Training And Development | Reward System | Performance Appraisal | Career Planning |                            |
| 1   | Tariq Rafique et al. (2024)                  | Enhancing Organizational Performance Through Competency-Based Human Resource Management: A Novel Approach To Performance Evaluation             | Pakistan       | General Organizations         | No                        | No                       | No            | Yes                   | No              | Survey and Interview       |
| 2   | Ai-Yong Zhu et al. (2024)                    | Subjective learning gain from a simulation based health management course: a mixed methods study                                                | China          | Health Management             | No                        | Yes                      | No            | No                    | No              | Survey and Interview       |
| 3   | Zulmi Ramdani et al. (2024)                  | Competency-Based Human Resources (HR) Development in the Digital Era                                                                            | Indonesia      | Digital and Technology Sector | Yes                       | Yes                      | No            | No                    | Yes             | Survey                     |
| 4   | Stephanie Vaughn et al. (2023)               | Inside Looking Out: Updated Competency Model for Professional Rehabilitation Nursing Practice                                                   | Usa            | Health Care System            | No                        | No                       | No            | Yes                   | No              | Not Mentioned              |
| 5   | G V Epikhina et al. (2023)                   | An analysis of the theoretical and methodological aspects of the competency-based approach in personnel management: directions for modification | Russia         | Maritime                      | No                        | No                       | No            | Yes                   | No              | Not Mentioned              |
| 6   | Pingfen Li et al. (2023)                     | AMOS-based Analysis of Community Cadres Crisis Management Competency                                                                            | China          | Not Mentioned                 | No                        | Yes                      | No            | No                    | No              | Survey and Interview       |
| 7   | Kaouthar Mlaouhi et al. (2022)               | Use of Competency Management Methods and Tools in roject-based Organizations                                                                    | France         | Project-based Organizations   | Yes                       | No                       | No            | No                    | No              | Survey                     |
| 8   | Sitong Wang et al. (2022)                    | A Study on Nurse Manager Competency Model of Tertiary General Hospitals in China                                                                | China          | Health Care System            | Yes                       | No                       | No            | Yes                   | No              | Interviews                 |
| 9   | Fejfarová M., et al (2022)                   | Employee Training And Development and Competencybased Approach: any Relationship?                                                               | Czech Republic | Automotive Industry           | No                        | Yes                      | No            | Yes                   | Yes             | semi-structured interviews |
| 10  | Dr. Amin Mohamed Amin Abd El Motalieb (2021) | Competency Based Human Resources Management (Case study)                                                                                        | Dubai          | An Organization               | Yes                       | Yes                      | Yes           | Yes                   | No              | 79-item survey             |

| Row | Authors<br>(year)                            | Title                                                                                                                                                                                                           | Country        | Field of Industry                         | Dimensions of CBHRM       |                          |               |                       |                 | Instrument                 |
|-----|----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-------------------------------------------|---------------------------|--------------------------|---------------|-----------------------|-----------------|----------------------------|
|     |                                              |                                                                                                                                                                                                                 |                |                                           | Recruitment And Selection | Training And Development | Reward System | Performance Appraisal | Career Planning |                            |
| 11  | Lina Daouk-Öyry et al. (2021)                | Evidence-Based Management Competency Model for Managers in Hospital Settings                                                                                                                                    | Lebanon.       | Health Care System                        | No                        | Yes                      | No            | No                    | No              | semi-structured interviews |
| 12  | Bruno Henrique Rocha Fernandes et al. (2021) | Competence Management Models in Leading Brazilian Organizations                                                                                                                                                 | Brazil         | 95 Brazilian Organizations                | No                        | No                       | No            | Yes                   | Yes             | Not Mentioned              |
| 13  | Mohamad Nasaruddin Mahdzir et al. (2021)     | Integrating Competency Based-Management into Individual Development Plan For University Staff                                                                                                                   | Malaysia       | University Staff                          | No                        | Yes                      | No            | Yes                   | Yes             | Survey                     |
| 14  | Zeplin Jiwa Husada Tarigan et al. (2021)     | The effect of competency management on organizational performance through supply chain integration and quality                                                                                                  | Indonesia      | Manufacturing Companies                   | No                        | No                       | No            | Yes                   | No              | Survey                     |
| 15  | Andrej JERMAN et al. (2020)                  | Conceptual Key Competency Model for Smart Factories in Production Processes                                                                                                                                     | Italy          | Automotive Industry                       | -                         | -                        | -             | -                     | -               | Semi-Structured Interview  |
| 16  | Kristina Sedyastuti et al. (2020)            | Human Resources Competency at Micro, Small and Medium Enterprises in Palembang Songket Industry                                                                                                                 | Indonesia      | SMEs                                      | -                         | -                        | -             | -                     | -               | Survey and Interview       |
| 17  | Rahmat Sabuhari et al. (2020)                | The effects of human resource flexibility, employee competency, organizational culture adaptation and job satisfaction on employee performance                                                                  | Indonesia      | Finance Company                           | No                        | No                       | No            | Yes                   | No              | Survey                     |
| 18  | O Y Frolova et al.                           | The personnel competence qualification formation in the agroindustrial complex production systems: managerial aspect                                                                                            | Russia         | Agroindustrial Complex Production Systems | No                        | No                       | No            | Yes                   | No              | Not Mentioned              |
| 19  | Petra Horváthová et al. (2019)               | Methodology proposal of the creation of competency models and competency model for the position of a sales manager in an industrial organisation using the AHP method and Saaty's method of determining weights | Czech Republic | An Industrial Organisation                | Yes                       | Yes                      | No            | Yes                   | No              | Survey and Interview       |
| 20  | Mohammad Mahoud et al. (2019)                | Studying Human Resource Competency Models in Multiple Construction Project                                                                                                                                      | Iran           | Construction Projects                     | No                        | Yes                      | No            | Yes                   | Yes             | Interview                  |

| Row | Authors<br>(year)             | Title                                                                                                                                                                                | Country | Field of Industry              | Dimensions of CBHRM       |                          |               |                       |                 | Instrument                 |
|-----|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|--------------------------------|---------------------------|--------------------------|---------------|-----------------------|-----------------|----------------------------|
|     |                               |                                                                                                                                                                                      |         |                                | Recruitment And Selection | Training And Development | Reward System | Performance Appraisal | Career Planning |                            |
| 21  | Milena Vainieri et al. (2019) | Explaining performance in health care: How and when top management competencies make the difference                                                                                  | Italy   | Health Care System             | No                        | No                       | No            | Yes                   | No              | Survey                     |
| 22  | Hidehiko Adachi et al. (2019) | The effects of training managers on management competencies to improve their management practices and work engagement of their subordinates: A single group pre- and post-test study | Japan   | Finance Company                | No                        | Yes                      | No            | No                    | No              | semi-structured interviews |
| 23  | Tao Chen et al. (2019)        | How do project management competencies change within the project management career model in large Chinese construction companies?                                                    | China   | Construction Company           | No                        | No                       | No            | No                    | Yes             | survey                     |
| 24  | Jimmy Kansal et al. (2018)    | Development of a competency model for enhancing the organizational effectiveness in a knowledge-based organization                                                                   | India   | A Knowledge-Based Organization | No                        | Yes                      | No            | Yes                   | Yes             | Interviews                 |
| 25  | Frank Nana Kweku Otoo (2018)  | Human resource management (HRM) practices and organizational performance                                                                                                             | Ghana   | Hotel                          | Yes                       | Yes                      | No            | Yes                   | Yes             | Survey                     |

### Antecedents

Due to the lack of quantitative research supporting the identified antecedents, we have not investigated them extensively in detail. However, through the literature review, we have identified seven factors categorized into three themes: organizational factors (Organizational size, Organizational culture, The number of employees, and Type of organization), individual factors (HR manager's competence, Personal characteristics of top managers) and human resource policies (HRM policy).

### Consequences

Research has provided evidence of the effects of CBHRM, which we have analyzed and organized into three broad categories:

- employee outcomes (personal traits, skills, knowledge, attitude, motivation, behavior)
- organizational outcomes (job satisfaction, retention, involvement, commitment, engagement, performance, reputation, attractiveness)
- financial outcomes



## Discussion

Examining the trend of publications is an essential indicator of knowing the process of scientific development of a subject. The present study examined articles published from 2018 to 2023 that focused on evaluating CBHRM in OHS. As seen in Figure 2, 2019-2021 is the peak of publications in the field of CBHRM in OHS. In 2018, the lowest number of CBHRM in OHS papers were published. Based on our results, 3.83 papers per year were published. Most reviewed studies did not have a sufficient standard or provide a specific model for CBHRM evaluation. Therefore, they were excluded from the study process. On the other hand, many studies were systematic review articles not examined in the present study.

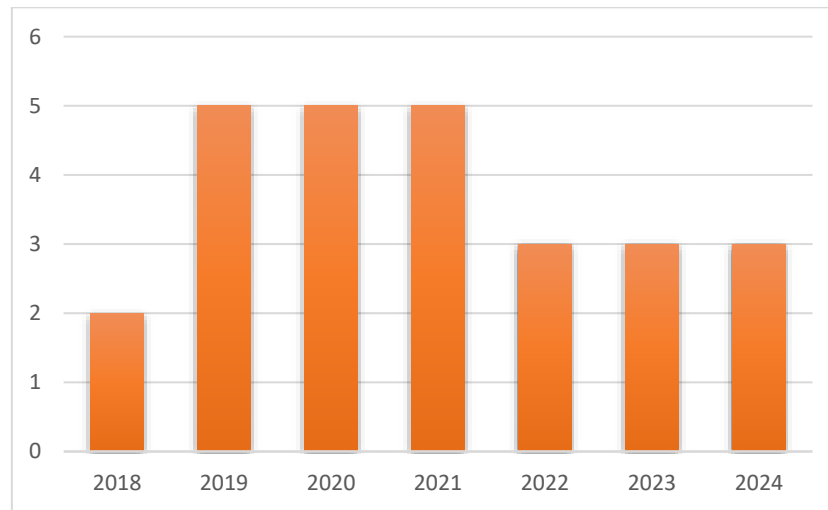


Figure 2. Distribution of papers by year of publication

As can be seen in Table 2, 43.5% of the studies collected the data using semi-structured interviews. 39.1% of the studies used surveys, and 17.4% used semi-structured interviews and surveys.

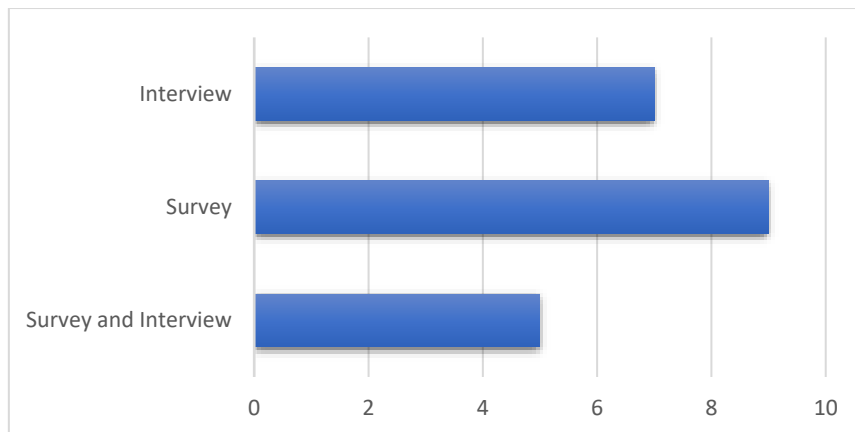
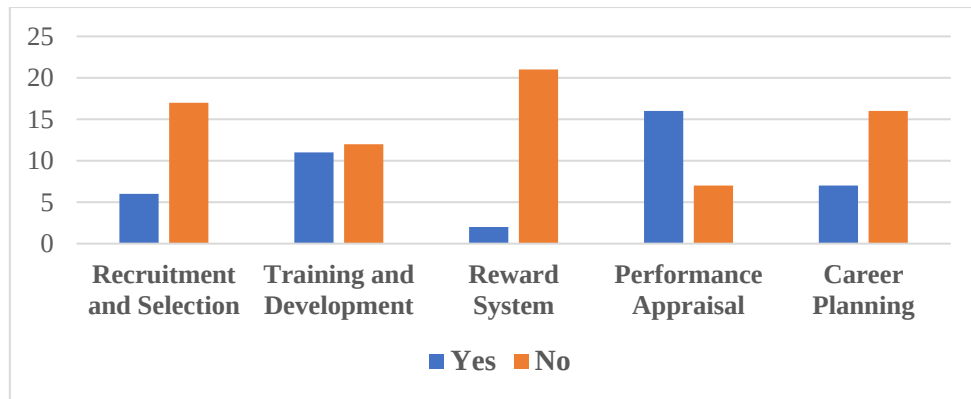


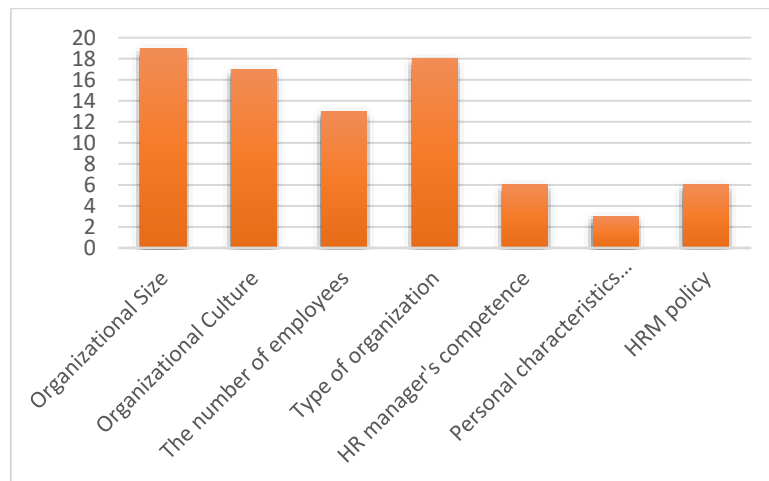
Figure 3. Instruments used to assess the CBHRM

As the literature review results showed, the CBHRM model had five dimensions. Based on the results, 26.1% of studies investigated Recruitment and Selection, 47.8% Training and Development, 8.7% Reward System, 69.6% Performance Appraisal, and 30.4% Career Planning. In recent studies conducted in the CBHRM field, Performance Appraisal has received more attention than other dimensions. The Reward System has received less attention than others. This review shows that organizations should consider all dimensions of the model to manage human-based competence in their organization effectively.

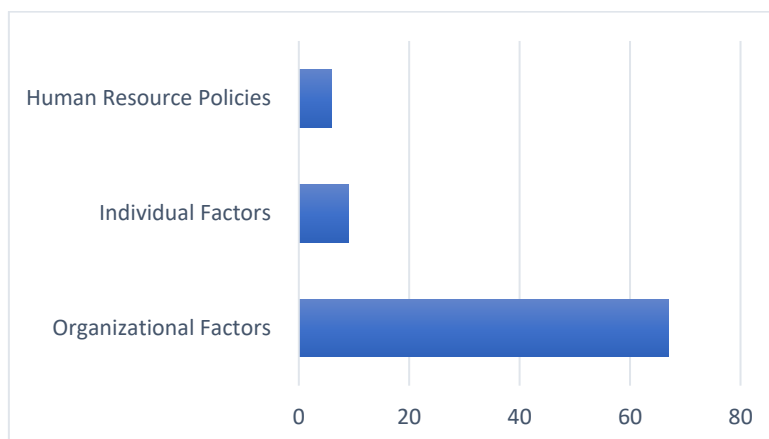


**Figure 4.** Distribution of the CBHRM model's dimensions

The results showed that organizational factors were examined 67 times, Individual Factors 9 times, and Human Resource Policies 6 times in the studies. Among the organizational factors, ORGANIZATIONAL SIZE was examined in 82.6% of the studies and accounted for the most statistics. The results are shown in Figure 5 and Figure 6.



**Figure 5.** Distribution of Antecedents' dimensions



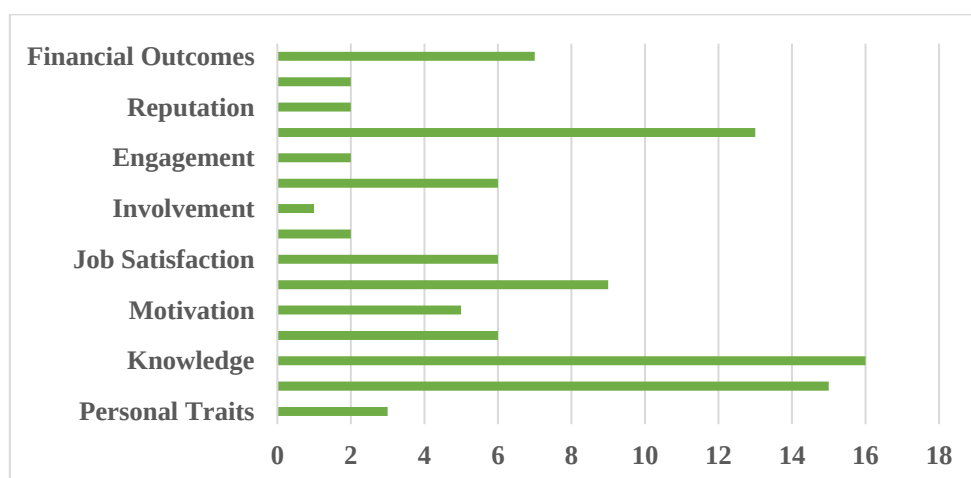
**Figure 6.** Distribution of the Antecedents' themes

The results of Table 2 show that using CBHRM models in the workplace literature review can positively affect employee outcomes, organizational outcomes, and financial outcomes.

**Table 2.** Outcomes of using CBHRM models in the workplace

| Outcomes                | Category         | Findings                                                         | References                           |
|-------------------------|------------------|------------------------------------------------------------------|--------------------------------------|
| Employee Outcomes       | Personal Traits  | HRM practices contribute to the development of employee outcomes | (27, 39, 40)                         |
|                         | Skills           |                                                                  | (27, 39-52, 57)                      |
|                         | Knowledge        |                                                                  | (27, 39-43, 45-54, 57)               |
|                         | Attitude         |                                                                  | (41, 43, 46-48, 51)                  |
|                         | Motivation       |                                                                  | (27, 41, 42, 48, 52)                 |
|                         | Behavior         |                                                                  | (27, 40, 41, 44, 47, 48, 50, 52, 55) |
| Organizational Outcomes | Job Satisfaction | HRM has a significant influence on organizational outcomes       | (27, 41, 48, 51, 54)                 |
|                         | Retention        |                                                                  | (41, 53)                             |
|                         | Involvement      |                                                                  | (27, 41)                             |
|                         | Commitment       |                                                                  | (27, 40, 43, 45, 47)                 |
|                         | Engagement       |                                                                  | (41, 55)                             |
|                         | Performance      |                                                                  | (27, 41, 44, 54, 57, 58)             |
|                         | Reputation       |                                                                  | (41, 56)                             |
|                         | Attractiveness   |                                                                  | (27, 41)                             |
| Financial Outcomes      |                  | Financial Outcomes are directly affected by HRM practices        | (27, 39, 42, 45, 46, 48, 50)         |

Figure 7 shows the frequency of these categories in different articles. The results showed that among employee outcomes, skills had the highest frequency of reviews in the articles, and personal traits were less noticed. Among organizational outcomes, performance was the most repeated, and retention, involvement, engagement, reputation, and attractiveness were the least noticed. The results showed that financial outcomes were examined in only 30.4% of the articles.


**Figure 7.** The frequency of outcome categories

According to Figure 8, among the reviewed studies, 57 percent of them had investigated employee outcomes, 36 percent of organizational outcomes, and 7 percent of financial outcomes studies.

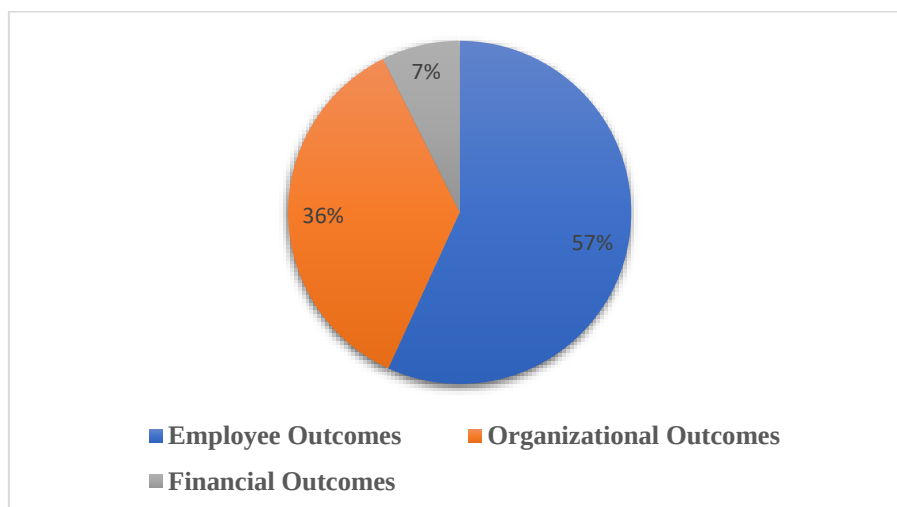


Figure 8. Frequency of outcomes

## Conclusion

This study elaborates on the key features, causes, effects, and proposed connections of the concept known as CBHRM in OHS. CBHRM in OHS covers several critical aspects, such as recruitment and selection, training and development, performance appraisal, reward system, and career planning. Organizational factors, individual factors, and human resource policies often influence these characteristics. The implication of implementing CBHRM in OHS is that it ultimately leads to improved outcomes for employees, organizations, and finances. This analysis will help senior managers, HR managers, and line managers understand the concept and determine where responsibility lies in further refining the definition of CBHRM in OHS.

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# IMPACT OF THE BUILT ENVIRONMENT ON THE PERCEPTION OF CAREGIVERS OF CHILDREN WITH MICROCEPHALY IN SPECIALIZED OUTPATIENT CLINICS: A NARRATIVE REVIEW

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**Abstract:** In recent years, Brazil has been the epicenter of an outbreak of the Zika virus, significantly increasing cases of microcephaly and affecting the development of many children. These patients require continuous and specialized care, with caregivers playing a key role in daily activities. The question then arises: how does the built environment impact the perception of caregivers of children with microcephaly in specialized outpatient clinics? A narrative review was carried out to organize the sources and strengthen the theoretical basis of the research, consulting the Web of Science, Scopus and CAPES Journal Portal databases, with articles published between 2020 and 2025, from November 2024 to February 2025. As a result, two dissertations were found, which explore how environments can be more accessible and inclusive, meeting the specific needs of people with physical disabilities and children with Zika Congenital Syndrome. The literature points to the scarcity of specific studies on the perception of caregivers in relation to these spaces, highlighting the need for further research into ergonomics in healthcare environments.

**Keywords:** Environmental perception; Microcephaly; Caregiver; Environmental ergonomics.

## Introduction

In the last ten years, a congenital infection has emerged as a global concern (WHO, 2016a), affecting countries such as France, the United States, El Salvador and, more intensely, Brazil, which has established itself as the epicenter of the Zika virus outbreak (Brazil, 2023). This outbreak was directly associated with a significant increase in cases of microcephaly in these regions.

According to the World Health Organization (WHO), microcephaly is defined as a clinical condition characterized by a baby's head being smaller than expected for its age and sex (WHO, 2016b). Depending on the degree of brain impairment, they present neurological, motor or respiratory alterations, requiring multidisciplinary monitoring in specialized outpatient clinics (Brazil, 2016a).

Given this clinical condition, these children depend on a caregiver to carry out their activities of daily living, as well as to support their development. According to the Brazilian Ministry of Health, a caregiver is someone with exceptional characteristics, such as love for humanity, solidarity and commitment. This role can be carried out by family members or members of the community, providing support to people of any age with physical or mental limitations, either on a paid or voluntary basis (Brazil, 2008).

According to Elali (2009), when visiting different environments, it is important to consider that each sector has variables that influence human behavior. These variables include “objective” aspects, such as lighting, temperature and noise, as well as “subjective” elements, such as the feeling of being crowded, welcomed, appropriated and the social climate.

The Brazilian Ministry of Health's National Humanization Policy adds that factors such as lighting, morphology, aromas, sounds, synesthesia, colors, art, care for external areas, privacy and comfort, when combined, favour the creation of more welcoming and harmonious environments. This contributes to well-being and challenges the idea that healthcare spaces are cold and impersonal (Brazil, 2013).

Lewin (1965) helps us to understand that individuals interpret the environment around them based on their experiences, needs and personal characteristics. He emphasizes that perception is not simply a passive reflection of the environment, but an active interaction between the individual and their context, influenced by psychological and social factors.



The way people interact with the environment around them, specially built spaces, influences various attitudes and behaviors, generating different perceptions. These perceptions originate from our sensations (Silva, 2023). Perception is an essential concept for understanding ambience, understood as the set of sensations, experiences, memories and emotions related to the social, physical, cultural and temporal context experienced by the person in each place (Tuan, 1980).

Environmental stimuli play a crucial role in explaining the sensations experienced by individuals. Therefore, when evaluating built environments, it is essential to consider the users' perception of the space to gain a deeper understanding of this interaction (Villarouco, 2011), allowing us to identify how these environments positively influence the performance of activities and the promotion of well-being (Ribeiro & Mont'Alvão, 2004).

Studying and understanding this interaction allows us to investigate the experiences of patients and their caregivers. These elements are essential for designing an environment that meets the specific needs of these users, promoting both functionality and well-being.

Indicating an approach that considers the diversity of people, their characteristics, interests and needs, aiming to create a comprehensive vision of how the environment can be properly adapted to them (Felippe *et al.*, 2024). In this way, the research in this study will use the principles of Environmental Ergonomics, based on understanding the interactions between human beings and the other elements of a system (IEA, 2020), considering the interaction between space, individuals and the activities to be carried out (Lobo & Villarouco, 2020).

This analysis presents an overview of the environmental perception of caregivers in an outpatient setting, based on a literature review that is part of an ongoing master's research project at the Federal University of Pernambuco. The study seeks to propose improvements to space, aiming to optimize the comfort and functionality of the environment for a more efficient care experience.

The question arises when we seek answers to the following question: How does the built environment influence the perception of caregivers of children with microcephaly in a specialized outpatient setting?

The narrative literature review was structured to connect the keywords of the topic under investigation, with the aim of improving the integration between Built Environment Ergonomics and the focus of the research, facilitating the understanding of the concepts and their interactions with the study. The results of this review present findings that illustrate the current state of the art, highlighting the connection between the built environment and the perception of the caregiver of children with microcephaly.

## **A brief review**

### ***Caregivers of patients with microcephaly***

In 1960, microcephaly was a hot topic. During a lecture in London, Valerie Cowie explained that the term has Greek origins and means “small head” (Cowie, 1960).

The World Health Organization defines microcephaly as a condition in which the size of the baby's head is smaller than the standard for age and sex (WHO, 2016a). The diagnosis is made by measuring the cephalic perimeter, an anthropometric parameter that correlates the size of the head to that of the brain (Brazil, 2017a). Microcephaly can be caused by various factors that affect brain development before or after birth. According to the Centers for Disease Control and Prevention (CDC, 2024), its causes include exposure to alcohol and drugs, maternal or infant malnutrition and congenital infections.

In the last decade, a congenital infection has received worldwide attention (WHO, 2016b), affecting several nations, especially Brazil, the epicenter of the Zika virus outbreak (Brazil, 2023). This outbreak has led to a significant increase in cases of microcephaly in these regions.

Several research studies and guidelines have been developed and published in Brazil (Brazil, 2016a, 2016b, 2017a) to highlight concerns about the impact of the microcephaly outbreak on infected babies. The studies confirmed that the Zika virus not only causes microcephaly, but also causes other serious brain damage, characterizing Zika Virus Congenital Syndrome.

Although the Ministry of Health ended the Public Health Emergency of National Concern in 2017, following the reduction in cases of microcephaly in Brazil (Brazil, 2017b), these children still need specialized care to minimize sequelae and promote their autonomy and social inclusion (Brazil, 2016a).

Given the severity of this clinical condition, these children need a caregiver to help them with daily activities and development. The caregiver is described as “a human being with special qualities, expressed by the strong trait of love for humanity, solidarity and giving”, as quoted by the Ministry of Health (2008, p. 8).

In most cases, mothers take on the role of primary caregiver for children with microcephaly, providing constant and specialized care (Sá *et al.*, 2020).

Since 2015, with the implementation of the National Plan to Combat Microcephaly by the Ministry of Health, early stimulation has become a fundamental strategy in monitoring children with disabilities. This is carried out in specialized clinics and outpatient clinics, with the aim of improving children's functionality and supporting their development (Brazil, 2016c).

These mothers face a stressful routine, taking their children in wheelchairs to appointments and therapies that are essential for their development, moving around different environments (Valim, 2021).

### **Ambulatories Specializes**

In 1944, the Brazilian Ministry of Health published *História e Evolução dos Hospitais* (History and Evolution of Hospitals), which was reissued in 1965. In it, the outpatient clinic is described as a service aimed at the diagnosis or treatment of patients who do not require hospitalization, serving people outside the hospital without the regular occupation of beds. Some hospitals were specialized, focusing on specific medical areas, such as tuberculosis, leprosy and nervous and mental illnesses, with their management being predominantly the responsibility of governments.

With the implementation of the Unified Health System (SUS), its organization became based on the creation of a regionalized and hierarchical network of services. This model encompasses different levels of care: basic care, which corresponds to the primary level; medium care, the secondary level; and high-complexity care, the tertiary level (Solla & Chioro, 2012).

According to these authors, to define the field of specialized care, which encompasses the areas of secondary care (medium complexity) and tertiary care (high complexity), we can mention medical specialties recognized in Brazil, such as allergy and immunology, gastroenterology, neurosurgery, anesthesiology, cardiology, pediatrics, among others.

In Brazil, these and other specialties are present in various institutions, such as Teaching Hospitals, which are health establishments linked to or affiliated with Higher Education Institutions. These hospitals serve as a field of practice for teaching activities in the health area and meet the established certification criteria (Brazil, 2015).

The architecture of these hospitals reflects the changes over time, with each phase requiring specific physical adaptations and progressive changes to the facilities. As this process is continuous and occurs unevenly, old and modern elements are interspersed, as shown in Figure 1, highlighting the need to understand this transformation (EBSERH, 2022).



Figure 1. Evolution of the architecture of the Oswaldo Cruz University Hospital (HUOC)  
Source: University of Pernambuco, 2018b.

According to the Design Parameters for Teaching and Research Hospitals of the EBSEH Network (Brazilian Hospital Services Company), projects should include covered areas to house many people and offer protection from the weather, spatial orientation elements to facilitate access to health services, as well as comfortable and clean waiting rooms that meet the needs of different profiles, including pediatric patients and their caregivers. The Ministry of Health's Ambience document (Brazil, 2010) emphasizes the importance of the physical environment in healthcare facilities as an essential factor in ensuring welcoming, effective and humanized care. Its guidelines promote the creation of a more welcoming hospital space that favors the well-being of all participants in the care process.

The National Humanization Policy in Brazil highlights elements such as lighting, morphology, aromas, sounds, colors and privacy as factors that influence hospital ambience. Integrating these aspects creates welcoming and harmonious environments, promoting well-being and challenging the idea that healthcare spaces are impersonal (Brazil, 2013).

### Environmental Ergonomics

According to the International Ergonomics Association (IEA, 2020), Ergonomics is a scientific discipline that studies the interactions between human beings and the various components of a system. In addition, it is a profession that uses theories, principles, data and methods in design, aiming to improve human well-being and the performance of the system.

Ilda and Buarque (2016) add that Ergonomics, also called Human Factors, is the study of how to adapt work to the human being, with the aim of reducing negative impacts on the worker.

Ergonomics applied to the Built Environment is a field of Ergonomics that focuses on the study of environments in use, with the aim of identifying and implementing improvements, considering how these spaces affect human activities. It adopts an approach that considers the diversity of people, their characteristics, interests and needs, with the aim of adapting the environment more effectively (Felippe *et al.*, 2024).

In this context, where the human being is seen as the focus of all ergonomic actions, it is unthinkable to study the built environment without considering the user's perception of that space. This makes it essential to include environmental perception in any ergonomic assessment of the environment (Villarouco, 2011).

Tuan (1980) examines the connection between human beings and space, highlighting the crucial role of personal experience in the perception of the environment. He states that space goes beyond a geometric abstraction, acquiring meaning through individual experiences and interactions. Tuan explains how people experience and perceive places based on their emotions, memories and sensory stimuli.

Environmental perception is fundamental to understanding the interactions between individuals and the built environment. It goes beyond subjective experience and is a key element that directly impacts the performance and well-being of users in architectural spaces (Bins Ely, 2003 *apud* Moraes, 2004).

## Results and discussions

During the literature review, it was difficult to find documents that addressed the environmental perception of caregivers in hospital environments, specifically in specialized outpatient clinics. Most of the research focused on the quality of life of caregivers.

The analysis was based on data from the Web of Science and Scopus platforms from November 2024 to February 2025, considering articles published between 2020 and 2025. Given the difficulty in finding specific materials, we expanded the search to the CAPES Journal Portal, including dissertations and theses in the search.

The search resulted in only two dissertations that specifically addressed the environmental perception of the built environment, as can be seen in Table 1.

*Table 1. Description of the literature review.*

| Dissertation   | Authors                                             | Year | Title                                                                                                                                                                  | Objective                                                                                                                                      | Results                                                                                                                                                                                                                                                                                                                                 |
|----------------|-----------------------------------------------------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Dissertation 1 | Farias, Marcella<br>Vívian Chaves<br>Lôbo Leitão de | 2021 | Ergonomic analysis of the built environment of physiotherapy rooms for patients with cerebral palsy: the case of the Pepita Duran clinic, Recife - PE                  | Propose ergonomic recommendations for physiotherapy rooms for patients with cerebral palsy.                                                    | The research concludes that the layout should be spacious for wheelchair users and include areas on the floor for activities, with the possibility of equipment or free spaces. Light, acoustic and thermal comfort conditions must comply with current standards, with adequate lighting for each activity.                            |
| Dissertation 2 | Coelho, Monique<br>Leite Galvão                     | 2022 | My child is growing up and now what? Exploring the environmental needs of children with Congenital Zika Syndrome (CZS) according to the perception of their caregivers | To explore the perception of caregivers about the environmental needs of children with SCZ, differentiating between barriers and facilitators. | Recognizing the daily needs of children with SCZ is crucial to guaranteeing their rights and social integration. It is necessary to implement specific public policies and have qualified professionals for family-centered care. Inclusive environments that promote social participation are essential for their healthy development. |

Both results address the importance of a suitable environment, but with different focuses. The study by Farias (2021) highlights the creation of accessible spaces for people with reduced mobility, emphasizing spacious layouts, areas for activities and light, acoustic and thermal comfort. The research also underlines the importance of integrating user perception and adopting ergonomic recommendations to optimize the environment according to users' needs.

The second result, by Coelho (2022), addresses the needs of children with Congenital Zika Syndrome, highlighting the importance of recognizing these needs to guarantee their rights and promote their social integration. The research emphasizes the creation of friendly environments that favor the social participation

and healthy development of these children. It also highlights the importance of public policies aimed at this group and the work of qualified professionals to provide family-centered care and skills development. Both results emphasize the importance of adapting environments to the needs of individuals, but while Farias' study (2021) focuses on the physical accessibility and ergonomics of spaces for people with disabilities, Coelho's study (2022) focuses on creating social and inclusive environments for children with SCZ. The research recognizes that the results therefore converge on the idea that adapting the environment to the needs of users is essential, but with different focuses: one on the physical and functional aspect and the other on the social and integration aspect.

## Conclusions

The built environment plays a fundamental role in shaping individuals' perceptions, attitudes and behaviors, especially in the context of caring for children with microcephaly.

Interaction with these spaces not only influences the day-to-day experience of caregivers, but also directly affects their emotional and physical well-being.

It is therefore important to emphasize that environmental ergonomics focuses on the adaptability and suitability of space to the tasks and activities carried out in it.

The initial purpose of the research was to identify in the literature review studies on how the built environment impacts the perception of caregivers of children with microcephaly during care in specialized outpatient clinics. However, the research revealed the difficulty in finding studies in the literature that address the perception of this group in relation to the built environment. This highlights the need for more research exploring this perspective, especially in the context of care and health spaces.

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# EXPOSIÇÃO OCUPACIONAL A AGENTES QUÍMICOS CANCERÍGENOS, MUTAGÉNICOS E/OU TÓXICOS PARA A REPRODUÇÃO EM CONTEXTO HOSPITALAR

## OCCUPATIONAL EXPOSURE TO CARCINOGENIC, MUTOGENIC AND/OR REPRODUCTIVE TOXIC CHEMICAL AGENTS IN A HOSPITAL SETTING

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### Abstract

**Introduction:** Exposure to chemical hazards in a hospital setting can vary depending on the hospital department or service involved and can come from a variety of sources, such as the use of sterilizing agents, disinfectants, solvents, hazardous medications, or anesthetic gases. To ensure continuous improvement of prevention measures, it is essential to regularly monitor the presence and levels of potentially toxic substances, both in workers (biological monitoring) and in the work environment (environmental monitoring). **Materials and methods:** This project aims to evaluate occupational exposure to carcinogenic, mutagenic and reproductively toxic chemical agents in a hospital context. A methodology proposed in the Technical Guide No. 2 by the State Health Department. At the hospital institution, different laboratories, the sterilization center and pharmaceutical services were evaluated. A total of 29 products classified as CMR were identified and 232 exposure situations were evaluated. **Results and discussion:** The execution of this project made it possible to carry out a detailed diagnosis of the situation, allowing not only the identification of products classified as CMR in use, but also the analysis of the context of workers' professional exposure to these products. This data will serve as a basis for planning future actions, aligned with the results obtained.

**Keywords:** occupational exposure, chemical agents, CMR, hospital context.

### Resumo

**Introdução:** A exposição a riscos químicos em contexto hospitalar pode variar de acordo com o departamento ou serviço hospitalar envolvido e pode ter diversas origens, como o uso de agentes esterilizantes, desinfetantes, solventes, medicamentos perigosos ou gases anestésicos. Para assegurar a melhoria contínua das medidas de prevenção, é essencial monitorizar regularmente a presença e os níveis de substâncias potencialmente tóxicas, tanto nos trabalhadores (monitorização biológica) quanto no ambiente de trabalho (monitorização ambiental). **Materiais e métodos:** Neste projeto pretende-se avaliar a exposição ocupacional a agentes químicos cancerígenos, mutagénicos e tóxicos para a reprodução em contexto hospitalar. Foi aplicada uma metodologia proposta no Guia Técnico N.º 2 da Direção-Geral da Saúde. Na instituição hospitalar foram avaliados diferentes laboratórios, a central de esterilização e os serviços farmacêuticos. Um total de 29 produtos classificados como CMR foram identificados e avaliadas 232 situações de exposição. **Resultados e discussão:** A execução deste projeto possibilitou realizar um diagnóstico detalhado da situação, permitindo não apenas identificar os produtos classificados como CMR em uso, mas também analisar o contexto de exposição profissional dos trabalhadores a esses produtos. Esses dados servirão como base para o planeamento de ações futuras, alinhadas aos resultados obtidos.

**Palavras-chave:** exposição ocupacional, agentes químicos, CMR, contexto hospitalar.

### Introdução

Os agentes químicos podem ser classificados de diferentes formas, de acordo com os efeitos indesejados que podem provocar com a sua utilização, podendo representar perigos físicos, se forem, por exemplo, explosivos, inflamáveis ou corrosivos, perigos para o ambiente ou perigos para a saúde.

Os efeitos adversos do agente químico são condicionados pelas suas características toxicocinéticas e toxicodinâmicas, ou seja, do seu percurso no organismo do trabalhador exposto e no seu mecanismo de ação, respetivamente. Quando ocorrem os efeitos sistémicos decorrentes da exposição a um agente químico, este surge em consequência da penetração ou absorção desse agente pelo organismo. Esse processo pelo qual o agente transpõe as membranas e entram na corrente sanguínea pode ocorrer de três formas: por via inalatória, via cutânea ou via digestiva (Thorne, 2015).

A exposição profissional aos agentes químicos CMR é resultado da combinação entre a intensidade e o tempo da exposição e podem ser considerados dois tipos de exposição: exposição aguda ou de curta duração e exposição crónica ou de longa duração. Para os profissionais dos estabelecimentos de prestação de serviços e cuidados de saúde, a exposição profissional crónica merece particular atenção, tendo em conta que muitas vezes os trabalhadores estão expostos a níveis reduzidos de concentração dos agentes, mas durante longos períodos como meses ou anos (Prista & Sousa Uva, 2002).

Relativamente aos agentes químicos CMR presentes em contexto hospitalar, são referidas diferentes substâncias, que tanto podem ser usadas na prática clínica, como em ações de desinfeção e esterilização ou até em serviços complementares como é o caso dos laboratórios de anatomia patológica. (Government of Alberta, 2011; Norton *et al.*, 2015; Pinhal, 2016).

### **Materiais e Métodos**

A metodologia aplicada para a realização deste projeto teve por base o questionário adaptado para a avaliação de risco da Ficha de Avaliação Integrada de Risco Profissional recomendada pela DGS no Guia Técnico n.º 2: Vigilância dos trabalhadores expostos a agentes químicos CMR e compreendeu as seguintes etapas:

- Submissão a apreciação pela Comissão de Ética da instituição;
- Identificação dos produtos químicos utilizados na instituição de saúde de acordo com a classificação do Regulamento CLP, através de dados disponibilizados pelo serviço de saúde ocupacional da instituição;
- Seleção dos serviços onde foi desenvolvido o projeto;
- Confirmação *in loco* dos produtos CMR em utilização em cada um desses serviços;
- Preenchimento do questionário adaptado contemplado na ficha de avaliação integrada da DGS;
- Avaliação de risco de acordo com a metodologia recomendada pela Direção-Geral da Saúde (DGS) no Guia Técnico n.º 2 sobre a vigilância dos trabalhadores expostos a agentes químicos CMR atribuindo uma pontuação de acordo com as opções indicadas no manual da DGS para determinar o Contexto de Exposição Profissional para cada situação.

### **Resultados e Discussão**

Os locais selecionados para a aplicação do projeto foram os seguintes: central esterilização, laboratório de anatomia patológica, laboratório de biologia molecular, laboratório central, laboratório de citometria de fluxo, laboratório de hematologia clínica, laboratório de microbiologia, serviços farmacêuticos. Em cada um dos locais selecionados e após a verificação da informação de segurança presente nos rótulos de cada produto, foram identificados os produtos CMR, indicados na Tabela 1.

Tabela 1. Identificação dos produtos CMR e respetiva distribuição.

| Produtos CMR                                             | Serviços Avaliados       |                                    |                                   |                     |                                    |                                    |                              |                        | Total de Locais de Exposição |
|----------------------------------------------------------|--------------------------|------------------------------------|-----------------------------------|---------------------|------------------------------------|------------------------------------|------------------------------|------------------------|------------------------------|
|                                                          | Central de Esterilização | Laboratório de Anatomia Patológica | Laboratório de Biologia Molecular | Laboratório Central | Laboratório de Citometria de Fluxo | Laboratório de Hematologia Clínica | Laboratório de Microbiologia | Serviços Farmacêuticos |                              |
| 2-Mercaptoetanol                                         |                          |                                    | X                                 |                     |                                    |                                    |                              |                        | 1                            |
| Ácido Bórico em Pó                                       |                          |                                    |                                   |                     |                                    |                                    |                              | X                      | 1                            |
| Ácido Quenodesoxicólico                                  |                          |                                    |                                   |                     |                                    |                                    |                              | X                      | 1                            |
| Ácido Salicílico TECHNICAL                               |                          |                                    |                                   |                     |                                    |                                    |                              | X                      | 1                            |
| Auramina O (C.I. 41000) para Microscopia                 |                          | X                                  |                                   |                     |                                    |                                    | X                            |                        | 2                            |
| Azul de Tripiano                                         |                          |                                    |                                   |                     |                                    | X                                  |                              |                        | 1                            |
| Borax                                                    |                          | X                                  |                                   |                     |                                    |                                    |                              |                        | 1                            |
| Carbol Fucsina de Ziehl-Neelsen Solução para Microscopia |                          | X                                  |                                   |                     |                                    |                                    | X                            |                        | 2                            |
| Cloreto de Cobalto (II) Hexahidratado                    |                          | X                                  |                                   |                     |                                    |                                    |                              |                        | 1                            |
| Clorofórmio                                              |                          |                                    |                                   |                     |                                    | X                                  |                              |                        | 1                            |
| Corante Vermelho Congo                                   |                          | X                                  |                                   |                     |                                    |                                    |                              |                        | 1                            |
| Cristal Violeta                                          |                          | X                                  |                                   |                     |                                    |                                    |                              |                        | 1                            |
| Diclorometano                                            |                          |                                    |                                   | X                   |                                    |                                    |                              |                        | 1                            |
| Fast Green FCF (C.I. 42053)                              |                          | X                                  |                                   |                     |                                    |                                    |                              |                        | 1                            |
| Fenol                                                    |                          |                                    |                                   |                     |                                    |                                    | X                            |                        | 1                            |
| Fenol Solução Aquosa 90%                                 |                          |                                    |                                   |                     |                                    |                                    |                              | X                      | 1                            |
| Formaldeído Solução 36.5 - 38%                           |                          | X                                  |                                   |                     |                                    |                                    |                              |                        | 1                            |
| Formalina 10% Neutra Tamponada                           |                          |                                    |                                   |                     |                                    |                                    | X                            |                        | 1                            |
| Formamida em Sonda                                       |                          |                                    |                                   |                     |                                    | X                                  |                              |                        | 1                            |
| Fucsina (C.I. 42510) para Microscopia                    |                          |                                    |                                   |                     |                                    |                                    | X                            |                        | 1                            |
| Lysing Solution BD FACSTM                                |                          |                                    |                                   |                     | X                                  |                                    |                              |                        | 1                            |
| Metotrexato                                              |                          |                                    |                                   |                     |                                    | X                                  |                              |                        | 1                            |
| Nitrato de Chumbo (II)                                   |                          | X                                  |                                   |                     |                                    |                                    |                              |                        | 1                            |
| Óxido de Crómio (VI)                                     |                          | X                                  |                                   |                     |                                    |                                    |                              |                        | 1                            |
| Óxido de Etileno                                         | X                        |                                    |                                   |                     |                                    |                                    |                              |                        | 1                            |
| Permanganato de Potássio                                 |                          | X                                  |                                   |                     |                                    |                                    | X                            | X                      | 3                            |
| Ponceau 2R                                               |                          | X                                  |                                   |                     |                                    |                                    |                              |                        | 1                            |
| Solução de Bouin                                         |                          | X                                  |                                   |                     |                                    |                                    |                              | X                      | 2                            |
| TRIzol Reagente                                          |                          |                                    |                                   |                     |                                    | X                                  |                              |                        | 1                            |
| <b>Total</b>                                             | <b>1</b>                 | <b>13</b>                          | <b>1</b>                          | <b>1</b>            | <b>1</b>                           | <b>5</b>                           | <b>6</b>                     | <b>6</b>               |                              |

Em metade dos locais avaliados, apenas se detetou a exposição a um produto classificado como CMR, nomeadamente na central de esterilização, nos laboratórios de biologia molecular, central e citometria de fluxo, os produtos óxido de etileno, 2-mercaptoetanol, diclorometano e lysing solution, respetivamente.

O local onde foram detetados mais produtos CMR foi o laboratório de anatomia patológica, com a exposição a auramina O, borax, carbol fucsina de Ziehl-Neelsen, cloreto de cobalto (II) hexahidratado, corante vermelho congo, cristal violeta, fast green FCF, formaldeído em solução 36.5 - 38%, nitrato de chumbo (II), óxido de crómio (VI), permanganato de potássio, Ponceau 2R e solução de Bouin, totalizando um conjunto de treze produtos.

No laboratório de microbiologia e nos serviços farmacêuticos foram detetados seis produtos em cada local. No laboratório de microbiologia estavam presentes auramina O, carbol fucsina de Ziehl-Neelsen, fenol, formalina a 10% neutra tamponada e fucsina. Nos serviços farmacêuticos estavam presentes ácido bórico, ácido quenodesoxicólico, ácido salicílico, fenol a 90% e solução de Bouin. O permanganato de potássio foi encontrado nos dois locais.

Por fim, no laboratório de hematologia clínica foram detetados cinco produtos CMR, nomeadamente azul de tripano, clorofórmio, formamida em sonda, metotrexato e trizol.

Depois da identificação dos produtos e da análise das respetivas fichas de dados de segurança, foi possível apurar qual a classificação de perigo específica de cada produto relativamente ao seu caráter carcinogénico, mutagénico e/ou tóxico para a reprodução. Foi ainda possível verificar qual a substância classificada como agente CMR no caso de produtos que são misturas. Os resultados encontram-se na Tabela 2.

**Tabela 2.** Classificação dos produtos CMR identificados.

|                                                          |                                       |            |           | Códigos de Advertência Identificados |      |      |      |      |      |      |  |
|----------------------------------------------------------|---------------------------------------|------------|-----------|--------------------------------------|------|------|------|------|------|------|--|
| Produto CMR                                              | Principal Substância CMR              | N.º CAS    | N.º CE    | H350                                 | H351 | H340 | H341 | H360 | H361 | H362 |  |
| 2-Mercaptoetanol                                         | 2-Mercaptoetanol                      | 60-24-2    | 200-464-6 |                                      |      |      |      |      |      | X    |  |
| Ácido Bórico em Pó                                       | Ácido Bórico                          | 10043-35-3 | 233-139-2 |                                      |      |      |      | X    |      |      |  |
| Ácido quenodesoxicólico                                  | Ácido quenodesoxicólico               | 474-25-9   | 207-481-8 |                                      |      |      |      |      |      | X    |  |
| Ácido Salicílico TECHNICAL                               | Ácido Salicílico                      | 69-72-7    | 200-712-3 |                                      |      |      |      |      |      | X    |  |
| Auramina O (C.I. 41000) para Microscopia                 | Auramina O                            | 2465-27-2  | 219-567-2 |                                      | X    |      |      |      |      |      |  |
| Azul de Tripano                                          | Azul de Tripano                       | 72-57-1    | 200-786-7 | X                                    |      |      |      |      |      |      |  |
| Borax                                                    | Borax                                 | 1330-43-4  | 215-540-4 |                                      |      |      |      | X    |      |      |  |
| Carbol Fucsina de Ziehl-Neelsen Solução para Microscopia | Fenol                                 | 108-95-2   | 203-632-7 |                                      |      |      | X    |      |      |      |  |
| Cloreto de Cobalto (II) Hexahidratado                    | Cloreto de Cobalto (II) Hexahidratado | 7791-13-1  | 231-589-4 | X                                    |      |      | X    | X    |      |      |  |
| Clorofórmio                                              | Clorofórmio                           | 67-66-3    | 200-663-8 |                                      | X    |      |      |      |      | X    |  |
| Corante Vermelho Congo                                   | Corante Vermelho Congo                | 573-58-0   | 209-358-4 | X                                    |      |      |      |      |      | X    |  |
| Cristal Violeta                                          | Cristal Violeta                       | 548-62-9   | 208-953-6 |                                      | X    |      |      |      |      |      |  |
| Diclorometano                                            | Diclorometano                         | 75-09-2    | 200-838-9 |                                      | X    |      |      |      |      |      |  |
| Fast Green FCF (C.I. 42053)                              | Fast Green FCF                        | 2353-45-9  | 219-091-5 |                                      |      |      | X    |      |      |      |  |
| Fenol                                                    | Fenol                                 | 108-95-2   | 203-632-7 |                                      |      |      | X    |      |      |      |  |
| Fenol Solução Aquosa 90%                                 | Fenol                                 | 108-95-2   | 203-632-7 |                                      |      |      | X    |      |      |      |  |
| Formaldeído Solução 36.5 - 38%                           | Formaldeído                           | 50-00-0    | 200-001-8 | X                                    |      |      | X    |      |      |      |  |
| Formalina 10% Neutra Tamponada                           | Formaldeído                           | 50-00-0    | 200-001-8 | X                                    |      |      | X    |      |      |      |  |

| Produto CMR                           | Principal Substância CMR | N.º CAS    | N.º CE    | Códigos de Advertência Identificados |      |      |      |      |      |      |
|---------------------------------------|--------------------------|------------|-----------|--------------------------------------|------|------|------|------|------|------|
|                                       |                          |            |           | H350                                 | H351 | H340 | H341 | H360 | H361 | H362 |
| Formamida Sonda                       | Formamida                | 75-12-7    | 200-842-0 |                                      | X    |      |      | X    |      |      |
| Fucsina (C.I. 42510) para Microscopia | C.I. Basic Red 9         | 569-61-9   | 209-321-2 | X                                    |      |      |      |      |      |      |
| Lysing Solution BD FACS               | Formaldeído              | 50-00-0    | 200-001-8 | X                                    |      |      | X    |      |      |      |
| Metotrexato                           | Metotrexato              | 59-05-2    | 200-413-8 |                                      |      |      | X    | X    |      |      |
| Nitrato de Chumbo (II)                | Nitrato de Chumbo (II)   | 10099-74-8 | 233-245-9 |                                      | X    |      |      | X    |      |      |
| Óxido de Crômio (VI)                  | Óxido de Crômio (VI)     | 1333-82-0  | 215-607-8 | X                                    |      | X    |      |      | X    |      |
| Óxido de Etileno                      | Óxido de Etileno         | 75-21-8    | 200-849-9 | X                                    |      | X    |      |      |      |      |
| Permanganato de Potássio              | Permanganato de Potássio | 7722-64-7  | 231-760-3 |                                      |      |      |      |      | X    |      |
| Ponceau 2R                            | Ponceau 2R               | 3761-53-3  | 223-178-3 |                                      | X    |      |      |      |      |      |
| Solução de Bouin                      | Formaldeído              | 50-00-0    | 200-001-8 | X                                    |      |      | X    |      |      |      |
| TRIZOL Reagente                       | Fenol                    | 108-95-2   | 203-632-7 |                                      |      |      | X    |      |      |      |

Dos vinte e nove produtos CMR identificados pode verificar-se que dez deles estão classificados como supostos ou conhecidos de provocar cancro (H350) e sete como suspeitos de provocar cancro (H351). Dois deles estão classificados como supostos ou conhecidos de provocar anomalias genéticas (H340) e dez deles como suspeitos de provocar anomalias genéticas (H341). Seis estão classificados como podendo afetar a fertilidade ou o nascituro (H360) e sete deles como apenas suspeitos (H361). Nos locais avaliados não foi identificado nenhum produto classificado de nocivo para as crianças alimentadas com leite materno (H362).

Foi possível ainda perceber que alguns produtos são misturas e, por isso, contêm na sua composição determinadas substâncias responsáveis pela sua classificação como CMR. Isso é verificado no caso do carbol fucsina de Ziehl-Neelsen e do trizol, que têm na sua composição fenol. É também o caso da formalina a 10% neutra tamponada, da solução de Lysing e da solução de Bouin, que têm formaldeído na sua composição. As substâncias mais frequentes nos diferentes locais avaliados são precisamente o fenol e o formaldeído.

Quanto às medidas de proteção coletiva mencionadas pelos trabalhadores, foi referida a existência de ventilação natural ou mecânica, bem como o manuseamento dos produtos químicos em câmara de fluxo laminar. Após a verificação das FDS foi possível verificar que, de forma geral, não são cumpridas ou conhecidas pelos trabalhadores todas medidas de proteção coletivas propostas pelas FDS.

Além da utilização do vestuário e calçado de trabalho, quanto aos equipamentos de proteção individual utilizados, foi sempre mencionada pelos trabalhadores a utilização de luvas de nitrilo ou latex. Nos laboratórios de hematologia clínica e de anatomia patológica foi mencionada a utilização de máscara cirúrgica (dispositivo médico) em algumas situações. Também no laboratório de anatomia patológica foi referida a utilização de proteção respiratória com filtro durante a manipulação de formaldeído. Nos serviços farmacêuticos foi mencionada a utilização de avental de proteção e máscara do tipo FFP3. À semelhança do que acontece com as medidas de proteção coletiva, verificou-se que também não é cumprida a utilização de todos os EPI que são propostos nas FDS, por exemplo, relativamente à utilização de proteção ocular e de luvas de material apropriado para contacto com produtos químicos.

Relativamente às medidas de primeiros socorros conhecidas pelos trabalhadores, em todas as situações foi apenas referida a lavagem com água em caso de contactos acidentais com os olhos ou pele e a remoção do vestuário em caso de derrame. Mais uma vez, os profissionais não mencionaram todas as medidas que são propostas nas FDS e não mostraram conhecimento sobre outras medidas a tomar em casos de emergência.

Na tabela 3, apresenta-se o número de trabalhadores expostos a agentes químicos CMR, por categoria profissional.

**Tabela 3. Trabalhadores expostos por categoria profissional.**

| <b>Categorias Profissionais</b>                  | <b>Número de Trabalhadores Expostos</b> | <b>Porcentagem de Trabalhadores Expostos</b> |
|--------------------------------------------------|-----------------------------------------|----------------------------------------------|
| Assistentes Operacionais                         | 27                                      | 31,0 %                                       |
| Enfermeiros                                      | 2                                       | 2,3 %                                        |
| Médicos                                          | 2                                       | 2,3 %                                        |
| Técnicos Superiores de Diagnóstico e Terapêutica | 51                                      | 58,6 %                                       |
| Técnicos Superiores de Saúde                     | 5                                       | 5,8%                                         |

No total, nos locais avaliados, estão expostos, a pelo menos um agente CMR, 87 trabalhadores, sendo que muitos deles estão expostos a mais que um agente. A categoria profissional com uma maior expressão relativamente ao nível de trabalhadores expostos é a dos TSDT, com um total de 51 trabalhadores expostos. Analisando os dados da tabela 4, é possível verificar quantos trabalhadores de cada categoria profissional estão expostos em cada local, e qual o agente em causa, assim como o resultado da graduação do contexto de exposição profissional que resultou das pontuações atribuídas sobre as condições operacionais para conjunto de trabalhadores.

**Tabela 4. Trabalhadores expostos por categoria profissional.**

| Produto CMR                              | Nº Trab.<br>Expostos | Categoria<br>Profissional | (A) | (B) | (C) | (D) | (E) | CONTEXTO DE<br>EXPOSIÇÃO<br>PROFISSIONAL |         |
|------------------------------------------|----------------------|---------------------------|-----|-----|-----|-----|-----|------------------------------------------|---------|
| Central de Esterilização                 |                      |                           |     |     |     |     |     |                                          |         |
| Óxido de Etileno                         | 1                    | AO                        | 1   | 5   | 1   | 3   | 1   | 11                                       | Médio   |
|                                          | 6                    | AO                        | 1   | 5   | 1   | 2   | 1   | 10                                       | Baixo   |
|                                          | 2                    | ENF                       | 1   | 5   | 1   | 2   | 1   | 10                                       | Baixo   |
| Laboratório de Anatomia Patológica       |                      |                           |     |     |     |     |     |                                          |         |
| Auramina O (C.I. 41000)                  | 7                    | TSDT                      | 1   | 2   | 3   | 3   | 3   | 12                                       | Médio   |
| Borax                                    | 7                    | TSDT                      | 1   | 2   | 3   | 3   | 2   | 11                                       | Médio   |
| Carbol Fucsina de Ziehl-Neelsen          | 7                    | TSDT                      | 1   | 2   | 3   | 3   | 1   | 10                                       | Baixo   |
| Cloreto de Cobalto (II)<br>Hexahidratado | 4                    | TSDT                      | 1   | 2   | 3   | 3   | 3   | 12                                       | Médio   |
| Corante Vermelho Congo                   | 7                    | TSDT                      | 2   | 2   | 3   | 3   | 2   | 12                                       | Médio   |
| Cristal Violeta                          | 7                    | TSDT                      | 2   | 2   | 3   | 3   | 2   | 12                                       | Médio   |
| Fast Green FCF (C.I. 42053)              | 7                    | TSDT                      | 1   | 2   | 3   | 3   | 3   | 12                                       | Médio   |
| Formaldeído Solução 36.5 -<br>38%        | 12                   | TSDT                      | 4   | 4   | 3   | 3   | 4   | 18                                       | Elevado |
| Nitrato de Chumbo (II)                   | 3                    | TSDT                      | 1   | 2   | 3   | 4   | 3   | 12                                       | Médio   |
| Óxido de Crômio (VI)                     | 7                    | TSDT                      | 2   | 2   | 3   | 3   | 3   | 13                                       | Médio   |
| Permanganato de Potássio                 | 7                    | TSDT                      | 2   | 2   | 3   | 3   | 2   | 12                                       | Médio   |
| Ponceau 2R                               | 7                    | TSDT                      | 2   | 2   | 3   | 3   | 2   | 12                                       | Médio   |
| Solução de Bouin                         | 3                    | TSDT                      | 1   | 2   | 3   | 3   | 1   | 10                                       | Baixo   |
| Laboratório de Biologia Molecular        |                      |                           |     |     |     |     |     |                                          |         |

| Produto CMR                               | Nº Trab.<br>Expostos | Categoria<br>Profissional | (A) | (B) | (C) | (D) | (E) | CONTEXTO DE<br>EXPOSIÇÃO<br>PROFISSIONAL |         |
|-------------------------------------------|----------------------|---------------------------|-----|-----|-----|-----|-----|------------------------------------------|---------|
| 2-Mercaptoetanol                          | 9                    | TSDT                      | 1   | 1   | 3   | 2   | 2   | 9                                        | Baixo   |
| <b>Laboratório Central</b>                |                      |                           |     |     |     |     |     |                                          |         |
| Diclorometano                             | 5                    | TSDT                      | 3   | 5   | 3   | 3   | 2   | 16                                       | Elevado |
| <b>Laboratório de Citometria de Fluxo</b> |                      |                           |     |     |     |     |     |                                          |         |
| Lysing Solution BD FACST™                 | 3                    | TSDT                      | 1   | 3   | 5   | 5   | 5   | 19                                       | Elevado |
|                                           | 2                    | MED                       | 1   | 3   | 5   | 5   | 5   | 19                                       | Elevado |
| <b>Laboratório de Hematologia Clínica</b> |                      |                           |     |     |     |     |     |                                          |         |
| Azul de Tripano                           | 4                    | TSDT                      | 1   | 2   | 5   | 3   | 2   | 13                                       | Médio   |
| Clorofórmio                               | 2                    | TSDT                      | 1   | 4   | 3   | 3   | 3   | 14                                       | Médio   |
|                                           | 1                    | TSS                       | 1   | 4   | 3   | 3   | 3   | 14                                       | Médio   |
| Formamida Sonda                           | 1                    | TSDT                      | 1   | 1   | 5   | 3   | 3   | 13                                       | Médio   |
|                                           | 1                    | TSS                       | 1   | 1   | 5   | 3   | 3   | 13                                       | Médio   |
| Metotrexato                               | 4                    | TSDT                      | 1   | 2   | 3   | 3   | 2   | 11                                       | Médio   |
|                                           | 4                    | TSS                       | 1   | 2   | 3   | 3   | 2   | 11                                       | Médio   |
| TRIZOL Reagente                           | 2                    | TSDT                      | 3   | 1   | 3   | 4   | 3   | 14                                       | Médio   |
|                                           | 1                    | TSS                       | 2   | 1   | 3   | 3   | 2   | 11                                       | Médio   |
|                                           | 2                    | TSS                       | 2   | 1   | 3   | 2   | 2   | 10                                       | Baixo   |
| <b>Laboratório de Microbiologia</b>       |                      |                           |     |     |     |     |     |                                          |         |
| Auramina O (C.I. 41000)                   | 9                    | TSDT                      | 3   | 2   | 3   | 2   | 4   | 14                                       | Médio   |
|                                           | 1                    | TSS                       | 3   | 2   | 3   | 2   | 4   | 14                                       | Médio   |
| Carbol Fucsina de Ziehl-Neelsen           | 9                    | TSDT                      | 3   | 2   | 3   | 1   | 4   | 13                                       | Médio   |
|                                           | 1                    | TSS                       | 3   | 2   | 3   | 1   | 4   | 13                                       | Médio   |
| Fenol                                     | 9                    | TSDT                      | 2   | 1   | 5   | 4   | 3   | 15                                       | Médio   |
|                                           | 1                    | TSS                       | 2   | 1   | 5   | 4   | 3   | 15                                       | Médio   |
| Formalina 10% Neutra Tamponada            | 15                   | TSDT                      | 2   | 2   | 2   | 3   | 2   | 11                                       | Médio   |
| Fucsina (C.I. 42510)                      | 9                    | TSDT                      | 3   | 2   | 3   | 2   | 4   | 14                                       | Médio   |
|                                           | 1                    | TSS                       | 3   | 2   | 3   | 2   | 4   | 14                                       | Médio   |
| Permanganato de Potássio                  | 1                    | TSS                       | 1   | 2   | 3   | 5   | 5   | 16                                       | Elevado |
| <b>Serviços Farmacêuticos</b>             |                      |                           |     |     |     |     |     |                                          |         |
| Ácido Bórico em Pó                        | 3                    | TSDT                      | 1   | 2   | 3   | 1   | 2   | 9                                        | Baixo   |
| Ácido quenodesoxicólico                   | 3                    | TSDT                      | 2   | 2   | 3   | 2   | 4   | 13                                       | Médio   |
| Ácido Salicílico TECHNICAL                | 3                    | TSDT                      | 1   | 2   | 3   | 1   | 2   | 9                                        | Baixo   |
| Fenol Solução Aquosa 90%                  | 3                    | TSDT                      | 1   | 1   | 3   | 1   | 2   | 7                                        | Baixo   |
| Permanganato de Potássio                  | 3                    | TSDT                      | 1   | 2   | 3   | 3   | 2   | 11                                       | Médio   |
|                                           | 3                    | TSDT                      | 3   | 2   | 3   | 1   | 2   | 11                                       | Médio   |
| Solução de Bouin                          | 3                    | TSDT                      | 1   | 2   | 3   | 1   | 2   | 9                                        | Baixo   |
| <b>Total</b>                              | <b>232</b>           |                           |     |     |     |     |     |                                          |         |

Legenda:

(A) – Quantidade utilizada (1 – 5)

(B) – Propriedades físicas que podem afetar a exposição do trabalhador (1 – 5)

(C) – Condições de trabalho/processo (1 – 5)

(D) – Frequência da utilização (1 – 5)

(E) – Duração da utilização. (1 – 5)



Dos 87 trabalhadores expostos nos diferentes serviços avaliados, resultou um total de 232 situações de exposição, sendo que muitos destes profissionais estão expostos a mais do que um agente CMR. Destas situações de exposição, 61 (26%) resultaram num contexto de exposição de risco Baixo, 148 (64%), a grande maioria, resultaram num contexto de exposição de nível Médio e 23 (10%) em contexto de exposição de risco Elevado.

Nenhuma das situações de exposição profissional identificadas resultou num contexto de exposição de nível Muito Elevado.

A distribuição pelos diferentes serviços revelou que o serviço que dispõe de maior número deste tipo de agentes é o Laboratório de Anatomia Patológica.

A distribuição pelas suas classificações demonstra que 10 dos 29 produtos CMR identificados estão classificados como produtos conhecidos ou supostos cancerígenos. Também 10 dos 29 produtos estão classificados como agentes químicos suspeitos de serem mutagénicos. Dos 29 produtos identificados, 12 são classificados em mais que uma categoria. Por exemplo, o cloreto de cobalto e o óxido de crómio estão inseridos nas três categorias: o cloreto de cobalto classificado como conhecido ou suposto cancerígeno e tóxico para a reprodução e suspeito mutagénico; o óxido de crómio classificado como conhecido ou suposto cancerígeno e mutagénico e suspeito tóxico para a reprodução.

Na generalidade, não são conhecidas pelos trabalhadores ou cumpridas as medidas de proteção coletiva constantes nas FDS. Quanto às medidas de proteção individual, na grande maioria das situações de exposição detetadas, os trabalhadores apenas utilizam luvas de nitrilo ou latex, quando as FDS referem a utilização de vestuário, luvas, óculos e proteção respiratória com características específicas. Não são, portanto, cumpridas as medidas relativas aos EPI previstas nas FDS.

Com relação às medidas de primeiros socorros que os trabalhadores mencionaram, pode afirmar-se foram muito limitadas e não estão de acordo com as medidas previstas nas FDS.

Sobre as categorias profissionais de trabalhadores expostos, pode afirmar-se que era esperado que os TSDT compusessem a categoria mais afetada, uma vez que estes são os trabalhadores que podem ser encontrados em maior número nos serviços avaliados. A única exceção verificada foi a central de esterilização, onde os trabalhadores representam apenas as categorias de enfermagem e assistentes operacionais.

No caso particular dos médicos que sofrem exposição no laboratório de citometria de fluxo, é importante referir que estes profissionais estão numa situação de exposição passiva, uma vez que não manipulam qualquer produto classificado como CMR, no entanto, partilham o espaço de trabalho com os TSDT que, por sua vez, fazem a utilização do produto.

Na sua globalidade, os resultados demonstram que a maioria das situações têm um contexto de exposição profissional médio. Os casos que resultaram num contexto de exposição baixo dizem respeito à central de esterilização, com o uso do óxido de etileno por ENF e AO, ao laboratório de anatomia patológica, com o uso de carbol fucsina de Ziehl-Neelsen e solução de Bouin por TSDT, ao laboratório de biologia molecular, com o uso do 2-mercaptoetanol por TDST, ao laboratório de hematologia clínica, com o uso de trizol por TSS e aos serviços farmacêuticos, com o uso de ácido bórico, ácido salicílico, fenol e solução de Bouin por TSDT.

Nos diferentes casos, os fatores determinantes para uma pontuação final baixa podem ser distintos: no caso da central de esterilização, com o uso do óxido de etileno, houve uma valoração baixa dos fatores quantidade utilizada, condições do processo e duração das tarefas; no laboratório de anatomia patológica, com o uso de carbol fucsina de Ziehl-Neelsen e solução de Bouin, valoração baixa na quantidade utilizada e duração das tarefas; no laboratório de biologia molecular, com o uso do 2-mercaptoetanol, valoração baixa na quantidade utilizada, propriedades físicas do produto, frequência e duração das tarefas; no laboratório de hematologia clínica, com o uso de trizol, valoração baixa nas propriedades físicas do produto e na frequência e duração das tarefas; nos serviços farmacêuticos, com o uso de ácido bórico, ácido salicílico, fenol e solução de Bouin, valoração baixa na quantidade utilizada e frequência das tarefas.

Os 5 casos em que é verificado o contexto de exposição profissional elevado são relativos ao laboratório de anatomia patológica, na utilização de formaldeído por TSDT, ao laboratório central, com a utilização de

diclorometano por TSDT, ao laboratório de citometria de fluxo, com a utilização da solução de Lysing por TSDT e exposição passiva de MED e ao laboratório de microbiologia, com a utilização de permanganato de potássio por TSS.

No caso do laboratório de anatomia patológica, com o formaldeído, houve uma alta valoração nos fatores quantidade utilizada, propriedades físicas do produto e duração das tarefas. No laboratório central, com diclorometano, valoração elevada nas propriedades físicas do produto. No laboratório de citometria de fluxo, com a utilização da solução de Lysing, valoração alta nas propriedades físicas do produto, condições do processo, frequência e duração das tarefas. No laboratório de microbiologia, com a utilização de permanganato de potássio, valoração alta na frequência e duração das tarefas.

O facto de nenhuma situação ter resultado num contexto de exposição profissional muito elevado é considerado positivo.

## Conclusões

A realização deste projeto num centro hospitalar universitário, permitiu fazer um diagnóstico de situação relativamente à utilização e exposição dos agentes químicos CMR, possibilitando não só identificar os 29 produtos classificados como CMR em utilização nos serviços avaliados da instituição, como também determinar o contexto de exposição profissional dos trabalhadores e esses mesmos produtos e planear ações de acordo com os resultados obtidos.

Concretamente, nesta instituição, os produtos que deverão ser alvo de maior atenção, pelo seu contexto de exposição profissional “Elevado”, são o Formaldeído Solução a 36.5 - 38%, o Diclorometano, o Lysing Solution BD FACS e o Permanganato de Potássio.

Os agentes que mais frequentemente ocorrem em situações de exposição são o fenol e o formaldeído, uma vez que são agentes que fazem parte da composição de alguns produtos químicos CMR.

Nem todos os produtos CMR identificados têm valores-limite de exposição ou indicadores biológicos associados. Também alguns destes produtos não possuem métodos de avaliação validados, tendo em consideração o NIOSH e a OSHA. Os produtos para os quais se verificou a existência destas duas condições (ter VLE ou indicador biológico e métodos de avaliação) foram o ácido bórico, o borax, o carbol fucsina de Ziehl-Neelsen, o cloreto de cobalto (II) hexahidratado, o clorofórmio, o diclorometano, o fenol, o fenol em solução aquosa a 90%, o formaldeído em solução a 36.5 - 38%, a formalina a 10% neutra tamponada, a lysing solution BD FACS, o óxido de crómio (II), o óxido de etileno, a solução de Bouin e o reagente Trizol.

Este projeto contou com algumas limitações, como a dificuldade de obter parte das fichas de dados de segurança dos produtos identificados, dado que os próprios serviços da instituição não possuem as mesmas. Também no preenchimento do quadro de avaliação do contexto de exposição profissional, relativamente ao campo das propriedades físicas do produto, existiu a dificuldade de obter informação sobre a pressão de vapor, uma vez que em alguns produtos líquidos essa propriedade não é determinada.

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# ADAPTAÇÃO INDIVIDUALIZADA DO POSTO DE TRABALHO EM CASOS CLÍNICOS COMPLEXOS: UM ESTUDO NA MEDICINA DO TRABALHO

## INDIVIDUALIZED WORKPLACE ADAPTATION IN COMPLEX CLINICAL CASES: A STUDY IN OCCUPATIONAL MEDICINE

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### Resumo

**Introdução:** A Medicina do Trabalho desempenha um papel essencial na promoção da saúde ocupacional, especialmente em trabalhadores com condições clínicas complexas. Adaptações laborais individualizadas são fundamentais para garantir a funcionalidade e a qualidade de vida dos mesmos. **Objetivo:** Ilustrar a relevância das adaptações laborais personalizadas para a funcionalidade e saúde física e psicológica de trabalhadores com quadros clínicos complexos, através da análise de um caso clínico. **Métodos:** Foi avaliado o caso de uma médica fisiatra de 41 anos com múltiplos antecedentes clínicos, incluindo amputações e doenças autoimunes. Foram adotadas medidas adaptativas com base no quadro clínico e exigências laborais, com vista na redução da sobrecarga física e na promoção do bem-estar da trabalhadora. **Discussão:** As adaptações implementadas, como evicção da marcha ou ortostatismo prolongados, redução da jornada laboral, pausas programadas e dias alternados de trabalho, mitigaram as limitações funcionais e psicológicas. Estas beneficiaram tanto a trabalhadora quanto a organização, destacando a importância de estratégias holísticas em casos complexos. **Conclusões:** A intervenção individualizada em Medicina do Trabalho promove a inclusão, funcionalidade e qualidade de vida. Além disso, ambientes laborais adaptados favorecem tanto os trabalhadores como a organização, reforçando a importância de políticas inclusivas.

**Palavras-chave:** Medicina do Trabalho, Aptidão Condicionada, Adaptação Laboral, Limitações.

### Abstract

**Introduction:** Occupational Medicine plays a crucial role in promoting occupational health, particularly for workers with complex clinical conditions. Individualized workplace adaptations are essential to ensure functionality and quality of life for such workers. **Objective:** To illustrate the importance of personalized workplace adaptations for the functionality, physical and psychological health of workers with complex clinical conditions, through the analysis of a clinical case. **Methods:** The case of a 41-year-old physiatrist with multiple health conditions, including amputations and autoimmune diseases, was evaluated. Adaptive measures were implemented based on her clinical condition and job requirements, aiming to reduce physical strain and promote her well-being. **Discussion:** The implemented adaptations, such as avoidance of prolonged walking or standing, reduced working hours, scheduled breaks, and alternating workdays, mitigated functional and psychological limitations. These measures benefited both the worker and the organization, emphasizing the value of holistic strategies in complex cases. **Conclusions:** Individualized interventions in Occupational Medicine promote inclusion, functionality, and quality of life. Furthermore, adapted work environments benefit not only workers but also organizations, reinforcing the importance of inclusive policies.

**Keywords:** Occupational Medicine, Fitness for Work, Workplace Adaptation, Limitations.

### Introdução

O Médico do Trabalho desempenha um papel central na promoção da saúde e bem-estar dos trabalhadores, assumindo responsabilidades que vão além da vigilância médica e da prevenção das doenças profissionais. Entre as suas funções, destaca-se a adaptação das condições laborais às necessidades individuais dos trabalhadores (Colin *et al.*, 2024).

O desafio torna-se maior nos casos de trabalhadores com quadros clínicos complexos. Doenças crônicas, como doenças autoimunes ou sequelas físicas graves podem representar barreiras significativas à atividade laboral, comprometendo a capacidade funcional do trabalhador (Op den Kamp et al., 2024). Estas situações exigem uma abordagem holística e personalizada, que considere o impacto da situação clínica na funcionalidade e no desempenho das tarefas laborais, mas também na saúde mental, qualidade de vida e integração social do indivíduo (Macdonald and Oakman, 2015).

A adaptação individualizada do posto de trabalho, fundamentada no conhecimento detalhado das tarefas desempenhadas e dos riscos ocupacionais a que o trabalhador está exposto, é uma ferramenta poderosa na promoção da saúde ocupacional. Esta abordagem permite mitigar riscos, prevenir o agravamento de condições pré-existent e garantir a continuidade da atividade profissional de forma sustentável. Desta forma, estas medidas trazem benefícios não só para os trabalhadores, mas também para as organizações (Tarro et al., 2020). Este artigo pretende ilustrar a importância da Medicina do Trabalho na gestão de casos de elevada complexidade, destacando o impacto das adaptações laborais na saúde física e psicológica do trabalhador, bem como na sua funcionalidade e qualidade de vida (Sonnentag et al., 2023). Através da análise de um caso clínico real, serão exploradas estratégias específicas para mitigar as limitações funcionais de uma trabalhadora com múltiplos antecedentes clínicos, sublinhando a relevância de intervenções individualizadas, centradas no trabalhador e fundamentadas na evidência científica.

### **Caso Clínico**

O caso clínico apresentado refere-se a uma mulher de 41 anos, médica fisiatra num hospital terciário situado a cerca de 50 quilómetros da sua área de residência. Exercia funções há dez anos, cumprindo um horário fixo diurno de 40 horas semanais. As suas tarefas consistiam essencialmente em atividade assistencial em consulta externa onde atendia, em média, cerca de 20 doentes por dia, e no acompanhamento de doentes internados, realizando visitas diárias a aproximadamente 10 pacientes distribuídos por diferentes serviços e pisos do hospital. Além disso, supervisionava programas de reabilitação, garantindo a correta implementação dos planos terapêuticos prescritos, e executava técnicas terapêuticas específicas na consulta externa de técnicas.

Foi avaliada em exame de saúde periódico, apresentando limitações funcionais que interferiam tanto nas atividades de vida diária quanto no desempenho das tarefas laborais.

Em abril de 2006, sofreu uma Meningite Meningocócica complicada com Púrpura Fulminante, resultando em amputação transmetatarsica bilateral, com cicatrização por segunda intenção e posterior realização de enxertos cutâneos. Além disso, houve amputação da falange distal do 4º dedo e das falanges intermédias dos 2º e 3º dedos da mão esquerda, além da falange intermédia do 4º dedo da mão direita. Posteriormente, em 2008, foi diagnosticada com Lúpus Eritematoso Sistémico, associado às Síndromes de Raynaud e de Sjögren. Associadamente, apresentava Síndrome de fadiga crónica. Mantinha seguimento em consulta externa de Medicina Física e de Reabilitação e de Reumatologia.

À data do exame, apresentava dor crónica incapacitante, predominantemente na região dos metatarsianos, exacerbada pelo ortostatismo prolongado e pela marcha, especialmente em pisos irregulares. A marcha prolongada (superior a 500 metros) frequentemente resultava em ulcerações nas áreas enxertadas, que obrigavam a repouso e cuidados diários de penso. Utilizava palmilhas pré-fabricadas em silicone, revestidas em tecido, e calçado adaptado com antepés largos e encontrava-se medicada com sulfato de hidroxycloquina 400mg/dia, pentoxifilina 400 mg 2x/dia, paracetamol/tramadol 325 mg/37.5 mg e anti-inflamatório não esteróide em SOS.

Ao exame objetivo, observaram-se cotos friáveis e pouco almofadados, com proeminências ósseas dolorosas à palpação. Identificaram-se múltiplas cicatrizes, resultado de úlceras de fricção prévias, sobretudo ao nível do primeiro metatarsiano esquerdo. Na face plantar, destacavam-se áreas de hiperqueratose associadas a dor moderada ao toque e com o membro em carga. Além disso, verificou-se a presença de hiperestesia em toda a região anterior do antepé, especialmente nas zonas enxertadas.

Em termos funcionais, apresentava uma autonomia modificada para as atividades de vida diária e para a atividade profissional, significativamente impactada pela dor e fadiga crónicas e pelos episódios recorrentes de ulceração. As exigências inerentes às suas funções, que incluíam a manutenção prolongada da posição ortostática durante a realização de procedimentos terapêuticos e consultas, bem como deslocamentos frequentes entre diferentes serviços hospitalares para visitas a doentes internados, resultavam numa sobrecarga física e mental considerável. O elevado número de consultas diárias intensificava esta sobrecarga, contribuindo para a exacerbação da dor e da fadiga crónicas.

Tendo em conta o quadro clínico da trabalhadora, foi determinada a aptidão condicionada, com a implementação das seguintes adaptações: evicção de atividades que envolvessem marcha ou ortostatismo prolongados, ajustes na carga de trabalho, com redução do número de consultas diárias e de visitas diárias a doentes internados, aumento no número e duração das pausas programadas, redução do horário laboral para metade do tempo habitual, introdução de dias intercalados de trabalho e descanso. Foi também reduzida a periodicidade da vigilância clínica pelo Médico do Trabalho.

## Discussão

A trabalhadora em questão apresentava um quadro clínico complexo, marcado por sequelas significativas de uma Meningite Meningocócica complicada com Púrpura Fulminante, associadas a amputações múltiplas, bem como diagnóstico de Lúpus Eritematoso Sistémico, Síndrome de Raynaud, Síndrome de Sjögren e Síndrome de fadiga crónica. Estas condições, em conjunto, acarretavam limitações funcionais importantes, especialmente em relação à tolerância ao ortostatismo e marcha e à gestão da dor e fadiga crónicas.

As amputações transmetatársicas, associadas às cicatrizes de enxertos, resultaram em cotos friáveis e áreas de hiperqueratose, com risco elevado de ulceração. Estudos indicam que o atrito, a pressão mecânica e a humidade podem agravar a condição da pele dos cotos em amputados (Meulenbelt *et al.*, 2007), o que pode aumentar o risco de ulceração e agravar a dor crónica. Adicionalmente, as condições autoimunes da trabalhadora contribuem para o comprometimento da vascularização e da perfusão das extremidades, exacerbando o risco de ulcerações e retardando a cicatrização tecidual (Ambler e Kaplan, 2024; Ture *et al.*, 2024; Souza *et al.*, 2003). Estas evidências suportaram a decisão de limitar atividades que implicassem marcha ou ortostatismo prolongado nesta trabalhadora, de forma a promover a cicatrização adequada das áreas afetadas e prevenir a deterioração óssea e complicações adicionais (Michael e David, 1994). Foram também implementados ajustes na carga de trabalho, incluindo a redução do número de consultas diárias para um máximo de 15 e a limitação das visitas a doentes internados a um máximo de 5 por dia. Além disso, foi aumentado o número e a duração das pausas durante o trabalho, estabelecendo-se intervalos programados de 10 minutos a cada 60 minutos de atividade. Estas medidas tiveram como objetivo reduzir o risco de agravamento das lesões e minimizar o desgaste físico e mental, permitindo uma gestão mais eficiente da fadiga e dor crónicas.

Outras medidas foram adotadas para promover a saúde e o bem-estar da trabalhadora. A redução do horário laboral foi essencial para mitigar a sobrecarga física e mental associada às exigências do trabalho e ao deslocamento diário de 50 quilómetros até ao local de trabalho. Essa medida procurou não só diminuir a frequência de deslocamentos, como proporcionar mais tempo para recuperação física e mental (National Guideline Centre (UK), 2021). A introdução de dias intercalados de trabalho e descanso foi uma estratégia relevante para garantir uma recuperação adequada, ajudando a equilibrar as exigências físicas e emocionais e promovendo um desempenho sustentável ao longo do tempo (National Guideline Centre (UK), 2021; Anand e Sevak, 2017).

Estas adaptações tiveram um impacto positivo não só na funcionalidade física, mas também no bem-estar psicológico da trabalhadora, que, em exame de saúde posterior, referiu melhoria das queixas algícas e da fadiga. Sentir-se valorizada e respeitada dentro das suas limitações é fundamental para mitigar os impactos psicológicos frequentemente associados a condições crónicas, como ansiedade ou depressão, e para preservar a autoestima da colaboradora. A preservação da funcionalidade e promoção da autonomia são fatores críticos na qualidade de vida de trabalhadores com condições crónicas (Zafar *et al.*, 2019; Sonnentag *et al.*, 2023; Op den Kamp *et al.*, 2024).



A articulação entre o Médico do Trabalho e outras especialidades, como a Reumatologia e a Medicina Física e de Reabilitação, desempenhou um papel fundamental na abordagem deste caso. Esta colaboração multidisciplinar possibilitou o desenvolvimento de uma estratégia holística, baseada no acompanhamento contínuo (Burger e Marincek, 2007). A vigilância periódica pelo Médico do Trabalho é também imprescindível para monitorizar a evolução clínica e assegurar que as medidas implementadas se mantêm adequadas às necessidades da trabalhadora.

Além das medidas adotadas, é relevante considerar outras adaptações, como a adequação das condições de trabalho e introdução de equipamentos ergonômicos para proporcionar maior conforto e segurança e reduzir o esforço físico (Kumar e Bezawada, 2019). A possibilidade de horários flexíveis também poderia ser considerada para atender às necessidades da trabalhadora (Green *et al.*, 2021).

Este caso destaca a relevância das intervenções personalizadas e multifacetadas na Medicina do Trabalho, que vão além da simples gestão das condições laborais, impactando diretamente a qualidade de vida e o bem-estar global do trabalhador. A interação entre as adaptações laborais e a saúde física e psicológica da trabalhadora ilustra como a implementação de medidas adequadas pode contribuir para a recuperação funcional e promoção de um ambiente de trabalho inclusivo e sustentável (Macdonald e Oakman, 2015; Shiri *et al.*, 2020). Além dos benefícios para o trabalhador, tais medidas favorecem a instituição, ao promoverem um aumento da produtividade e uma redução do absenteísmo e presenteísmo (Tarro *et al.*, 2020).

O caso sublinha, ainda, a necessidade de políticas públicas e empresariais que promovam a inclusão de trabalhadores com limitações, equilibrando os interesses organizacionais e o bem-estar dos colaboradores, o que tem um impacto positivo para toda a sociedade (Harter *et al.*, 2003).

## Conclusões

A intervenção em Medicina do Trabalho, fundamentada no conhecimento da história clínica e das condições profissionais do trabalhador, deve centrar-se na vigilância da saúde, na proteção contra riscos ocupacionais e na adaptação das tarefas às suas limitações, condicionalismos e capacidade funcional. As medidas adaptativas não só apoiam a recuperação física e funcional, como também contribuem para o equilíbrio psicossocial e para a melhoria da qualidade de vida, tanto no âmbito laboral quanto pessoal. Adicionalmente, o trabalho, quando ajustado às necessidades individuais, pode atuar como um elemento terapêutico, reforçando a autoestima, a integração social e o sentido de propósito do trabalhador. Assim, criar ambientes laborais inclusivos não é apenas uma responsabilidade ética, mas também uma estratégia que beneficia a organização e a sociedade como um todo.

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# CARACTERIZAÇÃO DOS ACIDENTES DE TRABALHO COM RISCO BIOLÓGICO NUM HOSPITAL TERCIÁRIO PORTUGUÊS ENTRE 2021 E 2024

## CHARACTERIZATION OF OCCUPATIONAL ACCIDENTS WITH BIOLOGICAL HAZARDS IN A PORTUGUESE TERTIARY HOSPITAL BETWEEN 2021 AND 2024

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### Resumo

**Introdução:** Os acidentes de trabalho com risco biológico representam uma ameaça significativa à saúde dos profissionais de saúde, podendo resultar na transmissão de agentes infecciosos, além de impactos psicológicos e económicos. A sua prevenção é crucial para garantir ambientes laborais seguros e saudáveis. **Objetivo:** Caracterizar os acidentes de trabalho com risco biológico em contexto hospitalar e contribuir para a implementação de medidas preventivas e corretivas. **Métodos:** Estudo observacional, transversal e retrospectivo, com análise de 115 notificações de acidentes de trabalho envolvendo risco biológico entre 2021 e 2024, num hospital terciário português. Foram analisadas variáveis demográficas e profissionais, características dos acidentes, resultados serológicos, medidas pós-exposição e impacto laboral, com análise estatística descritiva. **Resultados:** Enfermeiros foram os mais afetados (56,52%), e a maioria dos acidentes ocorreu por via percutânea com agulhas (73,04%), envolvendo sangue (71,30%). A imunidade contra o VHB foi identificada em 92,17% dos trabalhadores, e 6,09% receberam profilaxia pós-exposição. Apenas 1 caso (0,87%) resultou em incapacidade temporária absoluta para o trabalho. **Discussão:** Os resultados destacam a prevalência dos acidentes em contextos de elevado stress e a importância de medidas preventivas. **Conclusões:** A formação contínua, vacinação e implementação de medidas de segurança são essenciais para reduzir a ocorrência e os impactos destes acidentes.

**Palavras-chave:** Profissionais de saúde, Exposição ocupacional, Prevenção.

### Abstract

**Introduction:** Occupational accidents involving biological risk pose a significant threat to the health of healthcare workers, potentially resulting in the transmission of infectious agents, as well as psychological and economic impacts. Preventive measures are essential to ensure safe and healthy workplaces. **Objective:** To characterize occupational accidents involving biological risk in a hospital setting and contribute to the implementation of preventive and corrective measures. **Methods:** A retrospective, cross-sectional observational study was conducted, analyzing 115 notifications of biological risk accidents between 2021 and 2024 in a Portuguese tertiary hospital. Demographic and professional variables, accident characteristics, serological results, post-exposure measures, and occupational impacts were evaluated using descriptive statistical analysis. **Results:** Nurses were the most affected (56.52%), and most accidents occurred percutaneously with needles (73.04%) and involved blood (71.30%). Immunity to Hepatitis B virus (HBV) was confirmed in 92.17% of workers, and 6.09% received post-exposure prophylaxis. Only 1 case (0.87%) resulted in temporary total incapacity for work. **Discussion:** These findings emphasize the prevalence of accidents in high-stress contexts and the need for preventive measures. **Conclusion:** Continuous training, vaccination, and the implementation of safety measures are crucial to reducing the incidence and impact of these accidents.

**Keywords:** Healthcare professionals, Occupational exposure, Prevention.

## **Introdução**

O trabalho desempenha um papel essencial no desenvolvimento pessoal, constituindo uma fonte de realização e de contribuição para a sociedade. Contudo, as atividades laborais podem expor os profissionais a diversos riscos, levando à ocorrência de acidentes de trabalho e ao desenvolvimento de doenças profissionais, com impacto negativo na saúde e no bem-estar dos mesmos (Lira *et al.*, 2021).

Entre os riscos ocupacionais, destaca-se o risco biológico, particularmente entre profissionais de saúde. Estes são frequentemente expostos a fluidos orgânicos, o que os torna particularmente suscetíveis a contacto direto com agentes biológicos. Segundo dados da Agência Europeia para a Segurança e Saúde no Trabalho, os acidentes com picadas de agulha são os acidentes de trabalho com maior incidência no meio hospitalar (Agência Europeia para a Segurança e Saúde no Trabalho, 2005).

Os efeitos adversos destes acidentes podem ser graves, incluindo a transmissão de agentes patogénicos como os vírus da hepatite B (VHB) e hepatite C (VHC) e o vírus da Imunodeficiência Humana (VIH). Adicionalmente, os trabalhadores acidentados podem enfrentar níveis elevados de ansiedade e receio face a uma possível doença infecciosa (Castanha *et al.*, 2014; Oliveira e Gonçalves, 2014). Do ponto de vista económico, estes acidentes representam um problema relevante para as instituições e para a sociedade, acarretando custos diretos relacionados com profilaxia, tratamentos médicos e monitorização a longo prazo dos trabalhadores, bem como custos indiretos, como perda de produtividade e absentismo (Bakke *et al.*, 2010). Apesar da sua relevância, estes acidentes são frequentemente subnotificados pelos profissionais, que, ao não reportarem a sua ocorrência, dificultam a avaliação da real dimensão do problema. Por estes motivos, é de fulcral importância que não sejam desvalorizados e que sejam implementadas medidas eficazes de prevenção e monitorização dos mesmos (Barbosa *et al.*, 2015; Marković *et al.*, 2013).

O presente trabalho tem como objetivo caracterizar os acidentes de trabalho envolvendo risco biológico em contexto hospitalar. Ao fornecer uma análise destes acidentes, este estudo assume um papel importante no âmbito da Segurança e Saúde no Trabalho, contribuindo para a implementação de medidas preventivas e corretivas que promovam a segurança e a saúde dos trabalhadores, reduzindo a sua incidência e minimizando as consequências associadas.

## **Materiais e Métodos**

### **Desenho do estudo**

Foi conduzido um estudo observacional, transversal, descritivo, com análise retrospectiva dos acidentes de trabalho com risco biológico notificados pelo Serviço de Saúde Ocupacional (SSO) de um hospital terciário português entre os anos de 2021 e 2024.

### **Critérios de inclusão e exclusão**

Foram incluídos no estudo todos os acidentes de trabalho com exposição da pele, olhos, membranas mucosas ou contacto parentérico com fluidos biológicos potencialmente contaminados com agentes patogénicos, nomeadamente VHB, VHC e VIH. Não houve exclusão de nenhum caso notificado no período analisado.

### **Recolha de dados**

Para a recolha dos dados, foram consultadas as bases de dados dos acidentes de trabalho do SSO, assim como os processos clínicos eletrónicos dos trabalhadores envolvidos.

Foram recolhidas informações sobre as variáveis demográficas e profissionais dos acidentados, bem como os detalhes do acidente, incluindo o tipo de exposição, o fluido orgânico envolvido e o local do corpo atingido. Por fim, foram consultados dados sobre a incapacidade resultante e o seguimento médico dos trabalhadores.

### **Características serológicas da fonte de exposição**

Para avaliação da fonte de exposição, foram analisadas amostras de sangue venoso colhidas aquando do acidente para pesquisa dos seguintes marcadores serológicos: antigénio de superfície da hepatite B (AgHBs), anticorpos contra o Vírus da Imunodeficiência Humana (anti-VIH 1 e 2) e anticorpos contra o Vírus da Hepatite C (anti-VHC).

### Características serológicas dos profissionais acidentados

Relativamente aos acidentados, numa fase inicial, foi averiguada a evidência de imunidade para a hepatite B, quer por vacinação, quer por doença prévia. Nos casos em que tal não se verificou, foi realizada colheita de sangue venoso para estudo serológico, incluindo a pesquisa dos seguintes parâmetros: antígeno de superfície da hepatite B (AgHBs), anticorpos contra o antígeno de superfície da hepatite B (anti-HBs) e anticorpos contra o antígeno do core da hepatite B (anti-Hbc). Foram também requisitados os anti-VIH 1 e 2 e anti-VHC.

### Procedimentos de colheita e análise laboratorial

Todas as colheitas foram realizadas por profissionais qualificados e processadas no laboratório hospitalar.

### Análise dos dados

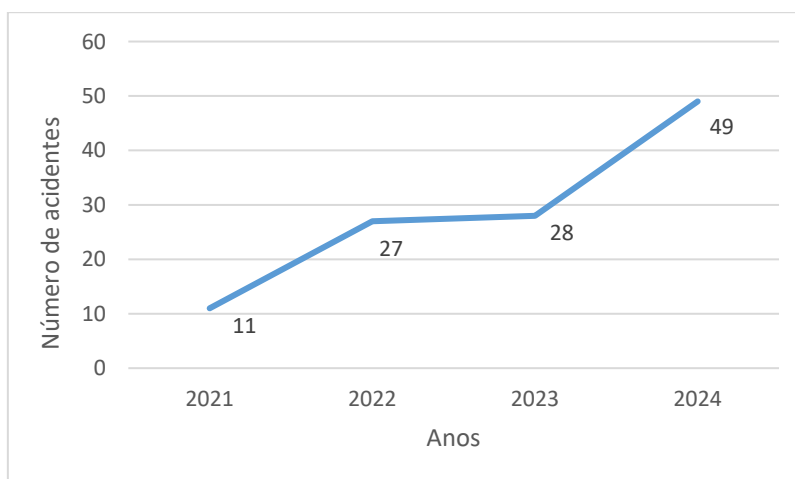
Foram calculadas as frequências absolutas (n) e as frequências relativas (%) para as variáveis qualitativas e as médias, mínimas, máximas e desvios-padrão para as variáveis quantitativas.

A análise dos dados foi realizada com recurso ao programa Microsoft Excel.

## Resultados

### Evolução dos casos

No período analisado, foram notificados ao SSO um total de 366 acidentes de trabalho, dos quais 115 envolveram risco biológico (31,42%). Destes 115 acidentes, 11 ocorreram em 2021 (9,57%), 27 em 2022 (23,48%), 28 em 2023 (24,35%) e 49 em 2024 (42,61%). A evolução dos casos ao longo dos anos está representada na Figura 1.



**Figura 1.** Evolução do número de acidentes envolvendo risco biológico ao longo do período estudado

### Trabalhadores acidentados

A maioria dos trabalhadores envolvidos era do género feminino (n= 104, 90,43%) e tinha idades compreendidas entre os 20 e os 63 anos, com uma média de  $35 \pm 9$  anos.

Em relação à profissão dos trabalhadores acidentados, a maioria era composta por enfermeiros (n = 65; 56,52%), seguidos por médicos (n = 34; 29,57%) e assistentes operacionais (n = 15; 13,04%). Foi reportado um caso por um técnico superior de diagnóstico e terapêutica (n = 1; 0,87%).

### Distribuição dos acidentes por serviço

Quanto à distribuição dos acidentes, os serviços com internamento reportaram o maior número de ocorrências (n = 33; 28,70%), seguidos pelo bloco operatório central (n = 18; 15,65%) e pelo serviço de urgência (n = 15; 13,04%). Na consulta externa ocorreram 10 casos (8,70%), enquanto na unidade de cuidados ambulatoriais (UCA) foram registados 8 casos (6,96%) e na imagiologia outros 8 casos (6,96%). Os restantes 23 acidentes (20,00%) ocorreram noutros serviços.

### Tipo de exposição, local afetado e material biológico envolvido

A maioria dos acidentes ocorreu por via percutânea com agulhas ( $n = 84$ ; 73,04%), predominantemente envolvendo sangue ( $n = 82$ ; 71,30%) e afetando as mãos e os dedos ( $n = 80$ ; 69,57%) e, em menor proporção, os pés ( $n = 2$ ; 1,74%). Verificou-se a ocorrência de 2 acidentes (1,74%) por via percutânea com agulhas envolvendo líquido pleural, atingindo as mãos e dedos.

Exposições percutâneas por bisturis ou outros cortantes corresponderam a 20 casos (17,39%), todos associados a sangue e limitados às mãos e dedos.

Acidentes por exposição a fluidos biológicos por salpico foram registados em 11 casos (9,57%) envolvendo sangue ( $n = 6$ ; 5,22%), secreções e saliva ( $n=3$ ; 2,61%) e urina ( $n = 2$ ; 1,74%). Estas exposições afetaram sobretudo os olhos ( $n = 5$ ; 4,35%), a mucosa oral ( $n = 4$ ; 3,48%) e a face ( $n = 2$ ; 1,74%).

### Características serológicas da fonte de exposição e dos acidentados

Relativamente às características serológicas da fonte de exposição, a maioria apresentava resultados negativos. Relativamente ao AgHBs, 96 fontes (83,48%) tiveram resultados negativos, enquanto 19 (16,52%) apresentaram resultados positivos ou não disponíveis. Em relação ao VIH, 97 fontes (84,35%) tiveram resultados negativos anti-VIH 1 e 2 e 18 (15,65%) positivos ou não disponíveis. Para os anti-VHC, 98 fontes (85,22%) eram negativas, enquanto 17 (14,78%) eram positivas ou não disponíveis.

No que diz respeito aos trabalhadores acidentados, a serologia anti-HBs, juntamente com a evidência de realização de pelo menos um esquema vacinal ou de doença prévia, revelou que 106 (92,17%) apresentavam imunidade, enquanto 9 (7,83%) não. Todos os trabalhadores apresentaram resultados negativos para anti-VIH 1 e 2 e anti-VHC ( $n = 115$ ; 100,00%).

### Medida pós-exposição

A profilaxia pós-exposição foi administrada em 7 trabalhadores (6,09%), sendo que 5 (4,35%) receberam profilaxia para o vírus da imunodeficiência humana (VIH) e 2 (1,74%) receberam imunoglobulina HBIG. O reforço vacinal para o VHB foi realizado em 8 trabalhadores (6,96%) (Tabela 1).

### Seguimento médico e incapacidade resultante

Quanto ao seguimento clínico, a maioria dos trabalhadores ( $n = 85$ ; 73,91%) teve alta na primeira consulta, 18 (15,65%) não compareceram às consultas de seguimento e 12 (10,43%) completaram seis meses de acompanhamento médico. Em apenas 1 caso (0,87%) foi registada uma incapacidade temporária absoluta (ITA) para o trabalho, obrigando o profissional a ausentar-se por um período de dois dias.

**Tabela 1.** Distribuição das Medidas Pós-exposição a risco biológico

| Medida Pós-Exposição          | Frequência absoluta (n) | Frequência relativa (% do total) |
|-------------------------------|-------------------------|----------------------------------|
| Profilaxia realizada para VIH | 5                       | 4,35 %                           |
| Imunoglobulina HBIG           | 2                       | 1,74 %                           |
| Reforço vacinal da hepatite B | 8                       | 6,96 %                           |

### Discussão

A percentagem de acidentes de trabalho com risco biológico identificada no presente estudo (31,42%) evidencia a prevalência significativa deste tipo de risco em ambiente hospitalar. Este valor encontra-se entre os reportados noutros estudos realizados em Portugal. Por exemplo, um estudo da Revista Portuguesa de Saúde Ocupacional (Afonso *et al.*, 2021) aponta que 40% dos acidentes de trabalho em instituições de saúde envolveram risco biológico, enquanto uma análise mais recente, realizada num hospital terciário português entre 2017 e 2022, revelou uma proporção de 26,3% (Pereira *et al.*, 2023). Estas variações podem refletir diferenças nas características das populações estudadas, na adesão às medidas de segurança e nos métodos de notificação utilizados, mas confirmam o impacto relevante deste tipo de acidente no contexto laboral hospitalar.

Enfermeiros e médicos, responsáveis pela execução de procedimentos que envolvem contacto direto com sangue e outros fluidos orgânicos, foram as categorias profissionais mais afetadas, representando mais de 85% dos casos. Os assistentes operacionais, apesar de também enfrentarem riscos biológicos significativos, contribuíram com uma menor proporção de acidentes. Em relação aos locais onde os acidentes ocorreram, os serviços com internamento reportaram o maior número de casos, seguidos pelo bloco operatório central e pelo serviço de urgência. Esta distribuição reflete a natureza e a complexidade das atividades realizadas nesses serviços, que frequentemente envolvem procedimentos invasivos e contextos de elevada pressão e stress, que favorecem a ocorrência de erros e acidentes (Cabuço, 2017; Mendes e Areosa, 2014).

As mãos foram o local mais frequentemente afetado, relevando a importância do cuidado no manuseio de agulhas e instrumentos. A maioria das exposições foi percutânea, principalmente envolvendo agulhas, em linha com estudos prévios (Agência Europeia para a Segurança e Saúde no Trabalho, 2005). O sangue esteve presente em mais de 90% dos casos, reforçando a necessidade de protocolos de segurança, dado o papel central deste fluido na transmissão de agentes infecciosos (Agência Europeia para a Segurança e Saúde no Trabalho, 2005). A elevada taxa de imunidade contra o VHB observada entre os trabalhadores acidentados evidencia a eficácia da vacinação e o papel indispensável dos serviços de saúde ocupacional na monitorização contínua da saúde dos trabalhadores e na implementação de medidas preventivas (Zanetti *et al.*, 2020). Contudo, a necessidade de reforços vacinais sublinha a importância de manter atualizados os registos do estado vacinal dos profissionais de saúde e de garantir a adesão às diretrizes de vacinação recomendadas pela Sociedade Portuguesa de Medicina do Trabalho (2017). É de particular importância a administração de profilaxia pós-exposição ao VIH e VHB, realizada numa pequena proporção dos acidentados, reflexo de uma avaliação individual criteriosa do risco de infeção (Sociedade Portuguesa de Medicina do Trabalho, 2017; World Health Organization, 2014).

Apenas um profissional apresentou incapacidade temporária absoluta (ITA) para o trabalho, decorrente de efeitos adversos da profilaxia pós-exposição ao VIH, o que sugere que a maioria dos acidentes não teve impacto significativo na capacidade funcional dos trabalhadores.

Outro ponto que merece destaque é o seguimento médico dos trabalhadores acidentados. Apesar de a maioria ter recebido alta após a primeira consulta, cerca de 16% dos trabalhadores não compareceu às consultas de seguimento, levantando preocupações sobre a adesão ao acompanhamento. A adesão inadequada pode resultar em complicações a longo prazo, como o desconhecimento de eventuais doenças infecciosas que poderiam ter sido prevenidas. Assim, torna-se essencial reforçar estratégias que promovam uma maior adesão ao seguimento médico (Soares *et al.*, 2018).

Além disso, a análise dos dados revelou um aumento no número de notificações ao longo dos anos do estudo. Este crescimento pode refletir uma maior sensibilização dos trabalhadores para a importância de notificar estes acidentes, bem como uma melhoria nos registos institucionais. Contudo, é importante considerar a possibilidade de subnotificação, uma realidade amplamente documentada em estudos semelhantes. A formação dos profissionais é crucial para garantir a documentação rigorosa dos acidentes, permitindo avaliar a real dimensão do problema e implementar medidas preventivas eficazes. Esta formação deve incluir não apenas a importância da notificação de incidentes, mas também o cumprimento rigoroso das normas de biossegurança, como o uso adequado de Equipamentos de Proteção Individual (EPI), o manuseamento seguro de amostras biológicas, o descarte correto de materiais cortopercutâneos e a adesão aos protocolos pós-exposição (Sociedade Portuguesa de Medicina do Trabalho, 2017; Barbosa *et al.*, 2015).

O desenho retrospectivo do estudo pode ter resultado em lacunas da informação, constituindo assim uma limitação do mesmo. No futuro, seria interessante explorar variáveis adicionais que possam contribuir para uma melhor compreensão dos acidentes de risco biológico e para o desenvolvimento de estratégias mais eficazes de prevenção e promoção da segurança no ambiente hospitalar. Exemplos incluem as condições de trabalho no momento do acidente, a análise do uso de equipamentos de proteção individual e a adesão às normas de segurança.



## Conclusões

O presente estudo representa uma amostra da realidade hospitalar no que diz respeito aos acidentes de trabalho com risco biológico. A análise detalhada destes acidentes permite identificar os fatores associados à sua ocorrência, contribuindo para a definição e implementação de medidas preventivas e corretivas. Destacam-se, entre estas medidas, a formação e a sensibilização dos profissionais de saúde sobre riscos ocupacionais e a adoção de medidas de segurança e equipamentos de proteção individual adequados. Adicionalmente, os exames de saúde desempenham um papel crucial neste contexto, permitindo monitorizar o estado de saúde dos trabalhadores, identificar precocemente possíveis exposições a agentes biológicos e assegurar uma resposta rápida e eficaz em caso de acidentes de trabalho. Estas ações, em conjunto, são fundamentais para garantir locais de trabalho mais seguros e saudáveis, ao mesmo tempo que contribuem para fortalecer a qualidade e a segurança dos serviços de saúde prestados.

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## Questões éticas e/ou legais

Nada a declarar.

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## AIRBORNE BACTERIA AND PARTICULATE MATTER IN POULTRY ENVIRONMENTS: A DOUBLE THREAT TO WORKERS' HEALTH

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### Abstract

The poultry industry poses a global health risk due to microbial contamination. Also, particulate matter (PM) may act as a vehicle for microbial dissemination. Understanding PM dynamics in poultry production environments is crucial for evaluating occupational exposure to airborne pathogens. This study aims to quantify PM contamination and assess occupational exposure to airborne bacteria in poultry pavilions (PP) throughout different stages of the production cycle. Air samples from indoor (n=47) and outdoor (n=20) PP were collected across various stages of the growth cycle (empty pavilion- sanitary control, 1st, 2nd, and 3rd weeks). For bacteria characterization the impactor MAS-100 was set to 100 L/min for 5 minutes and culture-based methods were performed. PM size fractions (PM<sub>0.5</sub>, PM<sub>1</sub>, PM<sub>2.5</sub>, PM<sub>5</sub>, and PM<sub>10</sub>) were measured using a Lighthouse Handheld Particle Counter at a flow rate of 2.83 L/min during 5 min. The highest bacterial loads and PM contamination occurred during the 3<sup>rd</sup> week, indicating a link between PM and the dissemination of airborne bacteria. PM<sub>10</sub> and PM<sub>5</sub> were dominant throughout the production cycle, highlighting their potential role in carrying pathogens to workers' respiratory systems. These findings emphasize the need to monitor PM and microbiological contamination in poultry farms to reduce worker health hazards.

**Keywords:** Particulate matter; Bacteria; Occupational health; Poultry farms; One Health.

### Introduction

The poultry industry poses a global health safety risk due to putative microbial contamination. The management of emerging pathogenic microorganisms, resistant to antibiotics and food-related stressors, is a major concern. Regarding bacteria, *Escherichia.coli*, *Staphylococcus* sp. (Bist *et al.*, 2022), and other species belonging to the WHO Bacteria Priority pathogens list (BPPL) (Gorny, 2022), were already isolated from poultry farms (Li *et al.*, 2021). Besides, several inflammatory agents are also present, including gram-negative bacteria metabolites - endotoxin, which has been linked to subjective symptoms and a reduction in respiratory airflow (Viegas *et al.*, 2013). Other concerns are related to Particulate matter (PM), which is regarded as one of the most harmful air pollutants in poultry production environments (Bist *et al.*, 2022; Derakhshani *et al.*, 2021). Wherever microbial sources exist, PM can serve as a vehicle for biological particles, functioning as a carrier for the respiratory system and boosting exposure to infections.

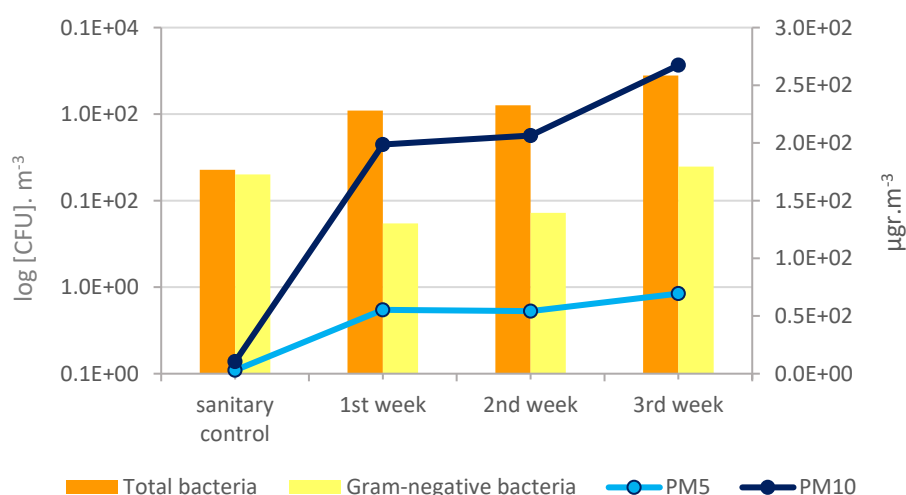
Particles that are significant to human health are inhalable particles with a diameter of less than 10µm referred to as thoracic particles, that are small enough to penetrate the respiratory tract (Gorny, 2022). Understanding PM dynamics is helpful when estimating occupational exposure to microorganisms, giving key data for the physical features controlling the transmission of airborne bacteria and exposure mitigation (Li *et al.*, 2021). Programs to reduce pathogens on farms helps to control issues related to the one health concept, since they improve workers and animals' health, reduce environmental contamination, and minimize water and vegetable pollution (Gomes *et al.*, 2022; 2023). Knowing the chemical and biological composition of the bioaerosols will help define the possible health effects related (Viegas *et al.*, 2014). Together, this information will support the development of mitigation techniques to reduce airborne transmission of PM and microorganisms from poultry production environments. Based on these assumptions this study aims to quantify particulate matter (PM) contamination and assess occupational exposure to airborne bacteria in PP.

## Material and methods

This study is part of a broader exploratory study that aims to assess microbiological contamination and occupational exposure in Portuguese poultry farms (n=5). The sampling campaign was conducted during Winter. Air samples from indoor pavilions (n=47) and outdoor (n=20) were collected on several stages of poultries' growth cycle (sanitary control- empty pavilions; 1<sup>st</sup>; 2<sup>nd</sup> and 3<sup>rd</sup> weeks;) by the impactor MAS-100, set at 100 L/min for 5 min, and using Polycarbonate (PC) filters (0.2 µm pore; 47 mm; Merck Millipore Ltd., Cork, Ireland) as performed by (Lanier *et al.*, 2010). To avoid particle bounce, 150 µL of sterile glycerol 10% [v/v] was added to the filters (Ferguson *et al.*, 2021). Filters were kept in petri plates at -20°C during transportation. The airborne dust collected by polycarbonate (PC) filters was extracted following Frankel and team members' protocol (2012). Briefly, 5 ml of 0.1% Tween 80 saline (0.9% NaCl) solution was added to the filters and extraction was accomplished via orbital shaking (500 rpm, 15 min). After extraction, 100 uL aliquot was spread onto petri dishes containing Tryptic soy agar (TSA) supplemented with nystatin (0.2%) and MacConkey agar (MAC) to cultivate total bacteria and gram-negative bacteria, respectively. TSA plates were incubated at 30°C, during 7 days and MAC plates were incubated at 37°C, during 7 days. Bacterial densities (CFU.m<sup>-3</sup>) were obtained. The Lighthouse Handheld Particle Counter HH3016-IAQ was used to measure particulate matter at five different sizes (PM<sub>0.5</sub>, PM<sub>1</sub>, PM<sub>2.5</sub>, PM<sub>5</sub>, and PM<sub>10</sub>), at a flow rate of 2.83 L/min during 5 min. Size fractions were used to estimate dust penetration within the respiratory system and their potential health effects (Viegas, *et al.*, 2012).

## Results and discussion

Regarding airborne bacteria levels, bacterial loads indoor surpassed those outdoors in 79% of the air samples collected (43 out of 47), supporting the assumption that PP are most likely a point source of microbial contamination (Chen *et al.*, 2021). Regarding total bacteria load, the median values increased throughout the weeks (sanitary control:  $2.27 \times 10^2$ ; 1<sup>st</sup> week  $1.10 \times 10^3$ ; 2<sup>nd</sup> week  $1.26 \times 10^3$ ; 3<sup>rd</sup> week  $2.79 \times 10^3$  CFU.m<sup>-3</sup>). The same frequency was observed on gram negative bacteria load, were the highest median value was observed on the 3<sup>rd</sup> week (sanitary control:  $2.01 \times 10^2$ ; 1<sup>st</sup> week:  $5.46 \times 10^1$ ; 2<sup>nd</sup> week  $7.23 \times 10^1$ ; 3<sup>rd</sup> week  $2.47 \times 10^2$  CFU.m<sup>-3</sup>). Considering PM concentration, the highest median values were also obtained the 3<sup>rd</sup> week for PM<sub>5</sub> (sanitary control:  $2.92 \times 10^1$  µgr.m<sup>-3</sup>; 1<sup>st</sup> week  $5.53 \times 10^2$ ; 2<sup>nd</sup> week  $5.42 \times 10^2$ ; 3<sup>rd</sup> week  $6.94 \times 10^2$  µgr.m<sup>-3</sup>) and for PM<sub>10</sub> (sanitary control:  $7.49 \times 10^1$ ; 1<sup>st</sup> week  $1.43 \times 10^3$ ; 2<sup>nd</sup> week  $1.52 \times 10^3$ ; 3<sup>rd</sup> week  $1.98 \times 10^3$  µgr.m<sup>-3</sup>) (Figure 1).



**Figure 1.** Airborne bacteria median load (log [CFU.m<sup>-3</sup>]) and particulate matter concentration (µgr.m<sup>-3</sup>) of the most prevalent size fractions (PM<sub>5</sub>; PM<sub>10</sub>) inside poultry pavilions following different stages of poultries growth cycle.

Several factors can influence bacteria load. High-density and poorly ventilated conditions may have contributed to a higher concentration of airborne bacteria during the 3<sup>rd</sup> week (Chen *et al.*, 2021; Peng & Biswas, 2020).

Assuming that PM contributes significantly to the spread of microorganisms (Chen *et al.*, 2021; Dias *et al.*, 2024), the highest level of PM contamination during the 3<sup>rd</sup> week might also justify the highest bacteria load during that stage. Regarding PM distribution indoors, from the different sizes evaluated (PM<sub>0.5</sub>, PM<sub>1</sub>, PM<sub>2.5</sub>, PM<sub>5</sub>, and PM<sub>10</sub>), PM<sub>10</sub> were prevalent during the production cycle (51.25% sanitary control; 63.36% on 1<sup>st</sup> week; 65.56% on the 2<sup>nd</sup> week; 65.09% on the 3<sup>rd</sup> week;). PM<sub>5</sub> were also frequent (19.97% sanitary control; 24.46% on 1<sup>st</sup> week; 23.35% on the 2<sup>nd</sup> week; 22.82% on the 3<sup>rd</sup> week;). The data indicate that coarse particles (2.5-10 µm) are the most significant PM in this environment. These PMs have the potential to exacerbate respiratory conditions such chronic obstructive pulmonary disease (COPD) and asthma. Also, smaller PM (< 7 µm) can reach the lung's gas exchange zone, leading to systemic effects (Shen *et al.*, 2023; Viegas *et al.* 2013). These data should be considered since workers avoid using respiratory protection during their working routines and so health risks are emphasized. Microbial assessments of poultry farms have previously revealed the presence of several microorganisms, including zoonotic pathogens that can operate as carriers of airborne illnesses. Regarding microbiological components, endotoxin, a significant constituent of gram-negative bacteria's outer membrane, is a substantial health hazard (Gomes *et al.*, 2023). Inhalation exposure to non-viable microbe components, such as endotoxins may also occur (Huneau-Salaün *et al.*, 2011), hence, examining non-viable components may be also relevant in determining pulmonary disease risk. (Li *et al.*, 2023; Peng *et al.*, 2020). From a One Health perspective, quantitative and qualitative research is required to fully understand this environment and determine the measures that should be taken to minimize exposure indoors and outdoors and control risk.

### Limitations

Air sampling is commonly used to evaluate occupational exposure. However, active sampling techniques have limitations in determining long-term exposure due to the brief sample duration of the device. The use of passive sampling methods on the other hand, allows accessing pollution levels over a long period. The potential of electrostatic dust cloths (EDC) and surface samples has already been well supported (Dias *et al.*, 2024; Viegas *et al.*, 2022) and future studies should follow this strategy.

### Conclusions

The majority of studies covering exposure assessments on poultry farms are based on measurements taken at a single stage of the production cycle. For an accurate occupational exposure assessment to airborne bacteria and PM contamination, this study comprises a wide sampling campaign covering several stages of poultries growth cycle. The highest level of airborne bacteria was found during the 3<sup>rd</sup> week. Similarly highest contamination of PM was found in the third week which may reflect the idea that particulate matter acts as a vector for disseminating microbiological agents. Besides, particle fractions PM<sub>5</sub> and PM<sub>10</sub> were dominant throughout the production cycle, suggesting that PM can carry potential pathogenic bacteria and their metabolites and reach workers respiratory system. We strongly recommend enforcing strict hygiene protocols during sanitary control, identifying contamination sources within pavilions (eg: cracks os walls, contaminated materials), and improving ventilation systems. Regarding workers protection, we emphasize the importance of using PPE, particularly RPE to reduce inhalation of PM carrying potentially pathogenic airborne bacteria. Further research should focus on species identification to complement the data obtained. Also, metabolites assessment (endotoxins) and bacteria antibiotic resistance profile should be carried out. Overall, this study underlines the need of microbial exposure assessments in poultry farms.

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# PROTOCOLO DE ATUAÇÃO EM PROFISSIONAIS DE SAÚDE COM EXPOSIÇÃO POTENCIAL AO VÍRUS DA HEPATITE B NUM HOSPITAL TERCIÁRIO PORTUGUÊS

## PROTOCOL FOR ACTION OF HEALTHCARE PROFESSIONALS WITH POTENTIAL EXPOSURE TO THE HEPATITIS B VIRUS IN A PORTUGUESE TERTIARY HOSPITAL

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### Abstract

**Background:** Hepatitis B virus (HBV) infection continues to be a public health problem, as healthcare professionals have a significant risk of illness due to occupational exposure to various organic fluids. **Objective:** Definition of the Occupational Health Service's approach to health professionals potentially exposed to the hepatitis B virus. **Method:** Reading articles on the topic published in the PubMed database, recommendations from the Centers for Disease Control and Prevention and description of the performance of the Occupational Health Service regarding the hepatitis b immunity status of Health Professionals. **Results:** Despite the measures implemented at national level to reduce the transmission of hepatitis B, such as vaccination, there is a significant number of non-immune workers. The Occupational Health Service plays a major key role in the management of this situation. occupational approach to HBV is analyzed, highlighting the prevention strategy through vaccination programmes and the procedures recommended for healthcare professionals who have had contact with the virus. **Conclusion:** Health professionals are at risk of infection by the HBV virus, and the Occupational Health Service is responsible for identifying and implementing appropriate measures, namely vaccination and confirmation of response to vaccine administration, as well as guidance for non-responders.

**Keywords:** Hepatitis B, Non-immune, Infection, Vaccine, Occupational Health.

### Resumo

**Introdução:** A infeção pelo vírus da hepatite B (VHB) continua a ser um problema de saúde pública, onde os profissionais de saúde têm risco significativo de doença pela exposição ocupacional a diversos fluídos orgânicos. **Objetivo:** Definição da abordagem de atuação do Serviço de Saúde Ocupacional em profissionais de saúde potencialmente expostos ao vírus da hepatite B. **Materiais e Métodos:** Leitura de artigos sobre o tema na base de dados PubMed, das recomendações do Centers for Disease Control and Prevention e descrição da atuação do Serviço de Saúde Ocupacional perante o estado da imunidade à hepatite B dos Profissionais de Saúde. **Resultados e Discussão:** Apesar das medidas implementadas a nível nacional para a diminuição da transmissão da hepatite B, como a vacinação, existem trabalhadores não imunes, tendo o Serviço de Saúde Ocupacional um papel primordial nesta gestão. São analisados os principais aspetos na abordagem ocupacional ao VHB, destacando a estratégia de prevenção por meio da vacinação e dos procedimentos recomendados aos profissionais de saúde que tiveram contacto com esse vírus. **Conclusões:** Os profissionais de saúde estão em risco de infeção pelo vírus da hepatite B, competindo ao Serviço de Saúde Ocupacional a sua identificação e implementação de medidas adequadas, nomeadamente vacinação e confirmação de resposta, assim como orientação de não respondedores.

**Palavras-chave:** Hepatite B, Não-imunes, Infeção, Vacina, Saúde Ocupacional.

### Introdução

O risco de infeção pelo VHB em profissionais de saúde (PS) é significativo. Entre os fluídos corporais, o sangue é o que contém as concentrações mais altas do vírus, sendo o principal veículo de transmissão. Em ambiente hospitalar, fluídos como o líquido cefalorraquidiano, pleural e peritoneal também são considerados potencialmente transmissores (Schillie *et al.*, 2018; Jeng *et al.*, 2023; Pappas, 2021). Apesar do sêmen e das



secreções vaginais estarem envolvidos na transmissão sexual do vírus, não são relevantes na transmissão ocupacional no contexto deste protocolo (Pappas, 2021).

A transmissão no local de trabalho pode ocorrer por via percutânea (como na picada acidental com agulhas), por contato com mucosas (como em salpicos nos olhos ou boca) ou através de pele não íntegra (como em feridas ou queimaduras). O risco de infecção após exposição percutânea depende da infecciosidade da fonte, variando de 6% a 62% (Schillie *et al.*, 2018; Pappas, 2021).

A prevenção inclui a vacinação e a monitorização da resposta imunitária, sendo que recomendações atualizadas de entidades como o *Centers for Disease Control and Prevention* enfatizam protocolos de vacinação para trabalhadores em risco de exposição, como os profissionais de saúde (Schillie *et al.*, 2018; Pattyn *et al.*, 2021). A implementação de programas de vacinação eficazes em muitos países resultou em uma diminuição significativa na incidência de novas infecções por hepatite B (Schillie *et al.*, 2018; Pattyn *et al.*, 2021). Contudo, existem ainda profissionais com esquema vacinal incompleto, com necessidade de reforço da vacina ou mesmo não respondedores à mesma, havendo necessidade de implementação de outras medidas ou orientações (Pappas, 2021).

Este trabalho tem como objetivo descrever e esclarecer a atuação do Serviço de Saúde Ocupacional perante o estado da imunidade dos profissionais de saúde à vacina da hepatite B nos exames de admissão, periódicos e ocasionais.

## **Materiais e Métodos**

Leitura de artigos sobre o tema na base de dados *PubMed* com os termos de pesquisa: hepatite B, imunidade, vacina, saúde ocupacional, assim como das recomendações do *Centers for Disease Control and Prevention* e descrição da atuação do Serviço de Saúde Ocupacional perante o estado da imunidade à hepatite B dos Profissionais de Saúde, nos exames de saúde.

## **Resultados**

### **Epidemiologia**

O número de mortes por hepatites virais está a aumentar, de acordo com o Relatório Global sobre Hepatites de 2024 da Organização Mundial da Saúde (OMS). Novos dados de 187 países mostram que o número estimado de óbitos aumentou de 1,1 milhão em 2019 para 1,3 milhão em 2022. Destes, 83% foram causadas pela hepatite B. Em 2022, ocorreram 2,2 milhões de novas infecções, sendo que 1,2 milhões foram por hepatite B (Pappas, 2021, Pattyn, 2021).

Em relação aos profissionais de saúde, no início da década de 1970, a prevalência da infecção pelo VHB foi estimada em aproximadamente 10 vezes a da população em geral. Em 1983, estimou-se que aproximadamente 17.000 infecções por HBV ocorreram em profissionais de saúde nos Estados Unidos. Mais ou menos na mesma altura (1981-1982), vacinas contra o VHB tornaram-se disponíveis e foram recomendadas em 1982 pelo Comité Consultivo sobre Práticas de Imunização (ACIP) para utilização de rotina em profissionais de saúde. Vários anos mais tarde, a epidemiologia do VHB nos Estados Unidos e em muitos outros países mudou como resultado dos esforços nacionais para eliminar a transmissão do VHB. Isto incluiu esforços para a vacinação universal de bebés e crianças em 1991 e a vacinação de “recuperação” de adolescentes em 1995. No seu conjunto, estas estratégias de vacinação foram associadas a um grande declínio na infecção pelo VHB entre profissionais de saúde (Pappas, 2021, Bhandari, 2020, U.S. Public Health Service, 2001, Beltrami *et al.*, 2000).

### **Transmissão**

O vírus da hepatite B é transmitido através de indivíduos infetados para indivíduos não imunes. Transmissão vertical, transmissão sexual, transfusão de sangue e contacto percutâneo ou com mucosas com fluido contaminado são formas de transmissão do vírus. Pode ocorrer, ainda, transmissão através de objetos contaminados com sangue, uma vez que o VHB pode sobreviver fora do corpo por pelo menos sete dias em sangue seco (Pappas *et al.*, 2021). Embora o DNA deste vírus possa estar presente em várias secreções

de indivíduos infetados, não há evidência de que possa ser transmitido por fluídos corporais além de sangue ou sêmen.

Em termos hospitalares, o risco de transmissão do VHB de um doente para um profissional de saúde é muito baixo como resultado da vacinação generalizada e da adoção de medidas de precaução básicas, resultando num declínio de transmissão de doença de 98% entre 1983 e 2010 (Schillie *et al.*, 2018, Pappas, 2021).

### **Prevenção**

A vacinação é o maior pilar na prevenção da transmissão do VHB. Assim, é importante a avaliação do esquema vacinal e realização de teste serológico, realizado em contexto de exame de saúde, antes de uma eventual exposição, com o objetivo de perceber se o profissional de saúde apresenta critérios de imunidade ou não à hepatite B (Schillie *et al.*, 2018, Pattyn, 2021, Albashir T. *et al.*, 2024).

Além disso, a todos os trabalhadores que possam ter exposição ocupacional de risco a fluídos biológicos, deve ser dada formação relativamente a medidas de prevenção como equipamentos de proteção individual adequados, identificação de potenciais exposições e adoção de medidas em caso de acidente de trabalho com exposição a fluídos orgânicos (Pappas, 2021).

Em Portugal, a vacina contra a hepatite B é gratuita e está integrada no Programa Nacional de Vacinação desde 1994 e a partir do ano 2000 passou a ser administrada a todos os recém-nascidos. O esquema de administração são três doses: a primeira ao nascimento, a segunda aos dois meses de idade e a terceira aos seis meses de idade (Pappas, 2021, Pattyn, 2021).

Contudo, no que diz respeito a adultos com exposição ocupacional a fluídos biológicos potencialmente infecciosos, a vacina também está recomendada conforme indicado na Circular Normativa N.º 15/DT de 15/10/2001, da Direção-Geral da Saúde. Assim, a vacina também não terá custos para estes grupos se administrada nos serviços de saúde da rede do Ministério da Saúde: profissionais dos serviços de saúde públicos; docentes e alunos das Faculdades de Medicina, Medicina Dentária e Enfermagem e Tecnologias da Saúde; Profissionais e utentes das Cooperativas de Educação e Reabilitação de Crianças Inadaptadas (CERCIS) ou de outras instituições destinadas a crianças com perturbações do desenvolvimento psicomotor e comportamental (Coelho *et al.*, 2022).

### **Exames de admissão**

À admissão do trabalhador, deve ser apurado o esquema vacinal realizado para o vírus da hepatite B, devendo apresentar as três doses já referidas num esquema de 0, 1 e 6 meses de intervalo e deve realizar estudo analítico com antigénio Hbs (AtgHbs), anticorpo anti-Hbs (Atc anti-Hbs) e anticorpo anti-Hbc (Atc anti-Hbc) (Schillie *et al.*, 2018, Albashir T. *et al.*).

### **Vacinação ausente**

No caso de não existir qualquer dose de vacina deverá ser realizado estudo analítico que contempla Atg HBs, Atc anti-HBc e Atc anti-Hbs para avaliar o estado serológico atual. Independentemente do valor do Atc anti-Hbs, com Atc anti-HBc negativo e sem nenhuma dose de vacina, o PS tem indicação para realizar esquema vacinal primário (Schillie *et al.*, 2018, Pappas, 2021). Contudo, se apresentar Atc anti-Hbs positivo, nenhuma dose de vacina e Atc anti-HBc positivo, significa que o PS já teve contacto com o vírus e desenvolveu imunidade, não necessitando de realizar qualquer esquema vacinal (Schillie *et al.*, 2018, CDC, 1982).

### **Vacinação incompleta**

Se o esquema vacinal for incompleto, ou seja, apenas uma ou duas doses administradas, o esquema vacinal não necessita de ser reiniciado na totalidade (Schillie *et al.*, 2018). Estas doses já administradas devem ser consideradas e deve ser completado o esquema com as restantes doses em falta. Se o esquema foi interrompido após a primeira dose, deve ser administrada a segunda dose assim que possível (desde que separada da primeira dose por 4 semanas), sendo que entre a segunda e terceira doses deve haver um intervalo de pelo menos 8

semanas. Por outro lado, se o trabalhador apresentar duas doses da vacina prévias ao exame de admissão, deve-se administrar a terceira dose assim que possível, sendo que tem de existir um intervalo mínimo de 8 semanas entre a segunda e terceira doses. Ainda, o intervalo de tempo entre a primeira e terceira doses tem de ser pelo menos 16 semanas. Doses de vacina administradas até 4 dias antes dos intervalos mínimos indicados são considerados válidas. Por outro lado, se as doses de vacina forem administradas em intervalo mais curto do que o recomendado, estas consideram-se inadequadas e devem ser readministradas respeitando os intervalos corretos (Schillie *et al.*, 2018).

### **Vacinação completa**

No caso do trabalhador apresentar as três doses, deve ser verificado o intervalo entre as mesmas e, apesar de o protocolado ser aos 0, 1 e 6 meses, são igualmente válidos outros esquemas desde que sejam cumpridos os intervalos mínimos necessários entre as doses. Assim, como referido previamente, terá de existir um intervalo mínimo de 4 semanas entre a primeira e segunda doses; intervalo mínimo de 8 semanas entre segunda e terceira doses; e intervalo mínimo entre primeira e última dose de pelo menos 16 semanas (Schillie *et al.*, 2018, Albashir T. *et al.*).

Após completar o esquema vacinal deve ser avaliada a resposta serológica 1 a 2 meses após a última dose e considera-se positiva se Atc anti-Hbs igual ou superior a 10, apresentando, assim, o profissional de critérios de imunidade para a hepatite B (Schillie *et al.*, 2018).

Noutra situação em que o trabalhador apresenta no exame de admissão as três doses e os intervalos adequados entre elas, realiza o estudo analítico e apresenta Atc anti-Hbs inferior a 10, ou seja, não há evidência de imunidade para a hepatite B, tem indicação para realizar reforço. No Serviço de Saúde Ocupacional em questão, realiza-se uma dose de reforço com reavaliação serológica 1 mês após, em que se Atc anti-Hbs igual ou superior a 10, considera-se imune e sem necessidade de repetição da serologia. Esta dose de reforço promove uma rápida proteção para o VHB, em que, num estudo, 88% das pessoas que a receberam, 30 anos mais tarde, apresentavam Atc anti-Hbs igual ou superior a 10, indicando imunidade persistente. Se, por outro lado, apresentarem anti-Hbs inferior a 10, terão de completar com mais duas doses, perfazendo um total de seis doses (três da vacinação primária, mais três do reforço). Nas três doses de reforço seguem-se os mesmo esquemas e intervalos de tempo entre doses que na vacinação primária. Contudo, também se poderá administrar um esquema completo adicional e fazer a reavaliação analítica apenas no final, sendo esta uma abordagem igualmente válida (Schillie *et al.*, 2018).

Um esquema vacinal completo resulta numa seroproteção superior a 90% em adultos saudáveis com menos de 40 anos (Schillie *et al.*, 2018).

### **Exames periódicos**

Um profissional de saúde que apresente num exame de saúde imunidade serológica para a hepatite B, ou seja, Atc anti-Hbs igual ou superior a 10, com três, quatro ou seis doses, não necessita de repetir estudo analítico. Se após um total de seis doses, o título Atc anti-Hbs for inferior a 10 não tem indicação para fazer mais doses de vacina, nem para repetir o estudo analítico, considerando-se assim um não respondedor (Albashir *et al.*, 2024, Saco *et al.*, 2018). Do mesmo modo, se apresentar imunidade serológica por contacto prévio com o vírus da hepatite B, isto é, Atc anti-Hbc positivo e Atc anti-Hbs igual ou superior a 10, também não tem indicação para repetir o estudo analítico em exame periódico futuro (Schillie *et al.*, 2018). Em situações de profunda alteração do estado imunitário, como em imunodepressão ou imunossupressão por fármacos biológicos ou corticoterapia prolongada ou, ainda, pela realização de hemodiálise, está recomendada analítica do estado da imunidade, mas sem determinação de serologia pós-vacinação (Albashir *et al.*, 2024). Sabe-se que, apesar de ser recomendada a vacina da hepatite B para doentes que vão ser submetidos a diálise, a resposta do anticorpo é muito menor do que em indivíduos saudáveis (Beran, 2008).

### **Exames ocasionais**

É necessário realizar um exame de saúde ocasional no caso de um trabalhador ter sido exposto acidentalmente a fluídos orgânicos, independentemente das doses de vacina realizadas e do seu estado serológico, após a observação no serviço de urgência.

Neste exame, o Médico do Trabalho, verifica os resultados analíticos pedidos pela Infeciologia no Serviço de Urgência da fonte e o *status* imunológico do trabalhador, neste caso, para o VHB, e avalia necessidade de realização de imunoglobulina, iniciar ou completar vacinação e indicação para testes serológicos posteriores (Schillie *et al.*, 2018).

### **Profissionais de Saúde Vacinados**

Para trabalhadores com vacinação primária completa com subsequente estudo analítico documentado com anti-Hbs igual ou superior a 10, não é necessário avaliar analiticamente a fonte para o vírus da hepatite B, nem realizar imunoglobulina, uma vez que o profissional de saúde tem critérios de imunidade para o VHB. Por outro lado, se o estado de imunidade para o VHB do profissional for desconhecido, mesmo que tenha esquema vacinal primário completo (3 doses), este deve colher análises para avaliar o anti-Hbs e a fonte, se conhecida, deve colher análises para avaliar o AtgHBs, ambos assim que possível, após a exposição. No caso de se manter desconhecimento do *status* do trabalhador ou este apresenta, entretanto anti-Hbs inferior a 10 e a fonte é AtgHBs positiva ou desconhecida, o PS deve receber uma dose de imunoglobulinas e ser revacinado. De notar que as imunoglobulinas e a dose de vacina da hepatite B podem ser administradas no mesmo momento desde que em membros diferentes. Posteriormente, o anti-Hbs deve ser avaliado um a dois meses após a última dose de vacina para documentar imunidade serológica. Contudo, o anti-Hbs só deverá ser realizado seis meses após a toma de imunoglobulinas, pois neste intervalo poderá ser detetável a imunoglobulina e não o anticorpo resultante da resposta imunitária. Se o PS apresenta anti-HBs inferior a 10 ou é desconhecido e a fonte revela AtgHBs negativo, o PS deve receber dose de vacina adicional no momento, não necessitando de realizar imunoglobulinas. E, mais uma vez, o teste anti-HBs deve ser realizado 1 a 2 meses após completar o esquema de revacinação (Schillie *et al.*, 2018).

No caso de se tratar de um profissional de saúde que apesar de vacinado com dois esquemas completos (6 doses no total) é não respondedor, isto é, anti-Hbs subsequente inferior a 10 e a fonte tem AtgHBs positivo ou é desconhecida, deve ser administrado ao PS duas doses de imunoglobulinas, separadas por intervalo de um mês, sendo que deve receber a primeira o quanto antes. O limite máximo para as imunoglobulinas serem administradas após a exposição é controverso, mas estudos indicam preferencialmente nas primeiras 24 horas, tendo um máximo de 7 dias na exposição percutânea e 14 dias na sexual. No caso de não respondedor com fonte negativa para AtgHBs, não é necessário realizar imunoglobulinas, nem nenhuma avaliação posterior. Em situação de não respondedores, não há indicação, como descrito anteriormente, de realizar mais nenhuma dose de vacina (Schillie *et al.*, 2018).

### **Profissionais de Saúde não vacinados ou vacinação incompleta**

Para trabalhadores não vacinados ou com vacinação incompleta, deve ser avaliado o AtgHBs no doente fonte logo que possível. Se a fonte é AtgHBs positivo ou desconhecido, deve ser administrada ao PS uma dose de imunoglobulina e completada a vacinação. Tal como referido, a toma de imunoglobulina e vacina pode ser realizada simultaneamente desde que em membros diferentes. Posteriormente, deve completar o restante esquema vacinal. O anti-Hbs deve ser avaliado um a dois meses após a última dose de vacina para documentar imunidade serológica.

No caso da fonte ser negativa, mesmo que o PS não seja vacinado ou tenha vacinação incompleta, não é necessário ser administrada imunoglobulina, mas há indicação para reiniciar o esquema vacinal ou completar o que estiver em falta.

Os trabalhadores não vacinados para VHB, com vacinação incompleta ou com anti-HBs desconhecido e que foram expostos a fonte AtgHbs positiva ou desconhecida, deve ser agendado um exame ocasional, 6 meses após a exposição e será reavaliado analiticamente com Atc anti-HBs e Atc anti-Hbc.

Após exposição acidental do PS ao VHB, não há necessidade de modificar os cuidados básicos entre este e os demais doentes para prevenir a transmissão do vírus e, ainda, não têm necessidade de uso de método de barreira para evitar transmissão deste vírus neste período. Contudo, neste mesmo período, não devem ser dadores de sangue nem órgãos (Schillie *et al.*, 2018).

O resumo da atuação perante OS com exposição potencial ao VHB é apresentado na tabela 1.

**Tabela 1.** Resumo da atuação em PS com exposição potencial ao VHB

| Situação do Profissional de Saúde (PS)                            | Estado da Fonte          | Ação Recomendada                                                 | Observações                                                                                              |
|-------------------------------------------------------------------|--------------------------|------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| <b>Vacinação primária e anti-HBs <math>\geq 10</math></b>         | Qualquer                 | Nenhuma ação necessária                                          | Profissional já tem imunidade.                                                                           |
| <b>Vacinação primária, mas estado imunológico desconhecido</b>    | Qualquer                 | Avaliação do anti-HBs do PS                                      |                                                                                                          |
| <b>Vacinado e anti-HBs <math>&lt; 10</math> (3, 4 ou 5 doses)</b> | Positivo ou desconhecido | 1 dose de imunoglobulina + revacinação                           | Administrar vacina e imunoglobulina em membros diferentes.                                               |
|                                                                   | Negativo                 | Revacinação                                                      | Sem necessidade de imunoglobulina.                                                                       |
| <b>Não respondedor (6 doses)</b>                                  | Positivo ou desconhecido | 2 doses de imunoglobulina (1ª dose imediatamente, 2ª após 1 mês) | Idealmente administrar imunoglobulina nas primeiras 24h, com um máximo de 7 dias (exposição percutânea). |
|                                                                   | Negativo                 | Nenhuma ação necessária                                          | Não há indicação para mais vacinas ou imunoglobulinas.                                                   |
| <b>Não vacinado ou vacinação incompleta (0, 1 ou 2 doses)</b>     | Positivo ou desconhecido | 1 dose de imunoglobulina + iniciar/completar esquema vacinal     | Administrar vacina e imunoglobulina em membros diferentes.                                               |
|                                                                   | Negativo                 | Iniciar/ completar esquema vacinal                               | Sem necessidade de imunoglobulina.                                                                       |

## Discussão

A infecção pelo vírus da hepatite B representa um risco significativo para profissionais que trabalham em ambiente hospitalar. Apesar dos avanços na vacinação e na prevenção, ainda há desafios significativos na garantia de imunidade adequada para todos os trabalhadores.

A avaliação do estado vacinal e respetiva resposta serológica são fundamentais para caracterizar a imunidade à hepatite B. No entanto, a validação de esquemas com intervalos específicos e a identificação de profissionais não respondedores requerem abordagens mais esclarecedoras, em que estes profissionais podem necessitar de reforços adicionais para alcançar imunidade adequada (Schillie *et al.*, 2018, Albashir T. *et al.*).

Contudo, quando se está perante um trabalhador não respondedor à vacina da hepatite B, atualmente, no Serviço de Saúde Ocupacional, não há mais propostas vacinais a realizar, estando este desprotegido e apenas há capacidade de atuação em contexto de exposição acidental. Deste modo, uma vacina diferente da do Plano Nacional de Vacinação seria interessante para este grupo não imune à hepatite B, como por exemplo a vacina *Fendrix*, que atualmente já é administrada em grupos de risco como doentes em pré-hemodiálise ou hemodiálise. Ainda, estratégias que aumentem a efetividade da vacina atual poderiam ser pensadas.

Assim, uma gestão proativa pelo Serviço de Saúde Ocupacional é crucial para mitigar o risco de transmissão ocupacional da hepatite B e proteger os profissionais de saúde.

### Conclusão

Embora avanços significativos tenham sido alcançados com a abrangência do Plano Nacional de Vacinação, desafios como esquemas vacinais incompletos ou com *timings* inadequados e profissionais não respondedores destacam a necessidade de abordagens mais sólidas. A integração de educação, medidas de proteção e protocolos claros fortalece a prevenção, onde o investimento em políticas consistentes é essencial para garantir a segurança dos trabalhadores.

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## EXPOSURE LIMIT VALUE TO RESPIRABLE CRYSTALLINE SILICA – A SYSTEMATIC REVIEW

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### Abstract

**Background:** Silicosis is a worldwide occupational fibrotic respiratory disease caused by inhaling respirable crystalline silica. There is a lack of knowledge about the limiting value of silica exposure in work labor or environment and compliance with this limit defined by national legislation. **Objective:** This systematic review describes how the limit value of silica dust exposure varies across the world and if people's exposure to silica dust exceeds the permissible level. **Methods:** The review considered peer-reviewed research articles published in English between 2018 and 2023. The study population included people who were exposed to silica dust. Twenty-one articles were eligible from Scopus, PubMed, and ISI Web of Knowledge databases. **Results:** The occupational and non-occupational populations were exposed to silica levels that exceeded the permissible value. Recognizing the non-accomplished standard limits is an opportunity to evaluate the production methods of industries, personal operating procedures, and guidelines of prevention rules. It is an opportunity to define environmental exposure limits for silica, rules for individual and collective protection, and screening strategies at regular occupational medicine consultations. **Conclusion:** The systematic review highlights the need for further research into guidelines for defining safe exposure silica dust limits and applying prevention measures.

**Keywords:** silica dust, silicosis, exposure limit value, occupational health.

### Introduction

Silicosis, a fibrotic respiratory disease, is caused by inhaling respirable crystalline silica, the earth's most abundant mineral (Leung *et al.*, 2012). Its toxicity arises from oxygen radicals that damage pulmonary cells, particularly alveolar macrophages, which release cytotoxic oxidants and inflammatory cytokines, driving fibrosis and inflammation (Rimal *et al.*, 2005). The global incidence of silicosis continues to rise due to increasing silica exposure in high-demand occupations and insufficient protective measures. In 2017, the Global Burden of Disease study reported 23,695 new silicosis cases, accounting for 39% of all pneumoconiosis cases (Hoy *et al.*, 2022).

The diagnosis of silicosis depends on a clear occupational history of substantial silica exposure and compatible radiological features. Chest radiography is the primary method of diagnosis with small round opacities distributed with upper-zone predominance. The radiologic evaluation is based on the International Labor Organization (ILO) classification of pneumoconiosis radiographs, and the diagnosis can be supported by a profusion score  $\geq 1/0$  per ILO classification (PNEUMOCONIOSES, 2002). Other possible diseases need to be ruled out to conclude the diagnosis (Fernández Álvarez *et al.*, 2015).

The widespread usage of crystalline silica in the industry has long been recognized as a serious occupational hazard. Occupational exposure occurs in a variety of industries, including architecture and construction, as well as mining, craftsmanship (stonecutting), cutting-edge technology (dental prosthesis), farming, trendy artificial stones (kitchen benchtop made of faux stone), and apparel (stone-washed jeans) (Hoy *et al.*, 2022).

In 1995, the World Health Organization began a campaign to eliminate silicosis worldwide by 2030, but silicosis remains a significant health issue internationally (Hoy & Chambers, 2020). Several foreign studies have indicated silicosis emerging in new settings, including environmental exposure. Environmental emissions of silica can arise from natural, industrial, and farming activities. In general, it is more likely that occupational crystalline silica exposures have been studied. The data available on non-occupational exposures to other forms



of silica are minimal (EPA, 1996). The innovative "environmental silicosis" concept remains understudied and can change the silicosis diagnosis paradigm. Non-occupational exposures to respirable crystalline silica are also possible, particularly in communities near silica-dust-generating sources. Non-occupational exposure can occur naturally due to desert dust and sandstorms in mountainous areas or dust emitted from industries that can affect nearby people through inhalation (Bhagia, 2012).

Inhaling respirable crystalline silica can have harmful effects on a person's health in addition to silicosis, such as lung cancer, chronic obstructive pulmonary disease, and pulmonary tuberculosis (Keramydas *et al.*, 2020). Targeted prevention requires a deeper comprehension of the influencing factors, including crystalline silica emissions and people's silica dust exposure (Xu *et al.*, 2023). There is a lack of knowledge regarding silica dust emissions in several industrial sectors and about the exposure limit value (ELV) and compliance of this limit defined by national legislation (Ehrlich *et al.*, 2021).

Putting it all together, how does the silica dust ELV vary across the world? Do people's exposure to silica dust exceed the permissible level? This systematic review aimed to find evidence in the literature on the worldwide limit value for exposure to silica dust and investigate the legislation compliance about silica powder exposure in the workplace and environment.

## Materials and methods

### Search strategy, inclusion criteria and data extraction

This systematic review was conducted following the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Page *et al.*, 2021). The search was performed by introducing the selected keywords into the search fields in Scopus, PubMed, and Web of Science. The authors considered that these three multidisciplinary databases were enough to cover the possible spectrum for the research. Additionally, the fields had to be adapted to provide comparable data and allow the reproducibility of work. The Boolean expression summarizing the combinations is ("dust" OR "dusting" OR "particulate" OR "powder") AND ("exposure limit" OR "emission limit" OR "limit value") AND ("crystalline silica"). This expression was broad enough not to exclude critical information initially. The research was carried out in June 2023.

The exclusion criteria were (1) Date—only papers published between 2018 and 2023 were included; (2) Type of document—only research articles were included; (3) Source type—only peer-reviewed journals were considered; and (4) Language—only articles written in English were included. All the records were managed with Endnote software, where the duplicate files were removed. To be included in the research, the focus of the remaining articles had to be on (1) presenting the acceptable silica exposure standard according to the different established committees on Occupational ELV; (2) accessing the measurements of personal exposure to respirable particles of respirable crystalline silica at any context, occupational and non-occupational, and (3) discussing the fulfillment of the ELV of silica exposure. New potentially relevant reports were identified through the eligible papers' forward and backward citation tracking.

The following information was extracted: (1) study characteristics: first author name, publication year, country; (2) type of study; (3) study objective; (4) source of exposure (such as occupational setting or non-occupational exposure); (4) information about the outcome of interest (ELV established and compliance with the standard rules) (Table 1).

### Quality assessment

To summarize the risk-of-bias assessments, a traffic light plot was created using the Robvis tool (McGuinness & Higgins, 2021) (Table 2).

## Results and Discussion

### Research Results

Over 288 articles were identified in the initial stages of the research, from which 195 were removed according to the exclusion criteria. The references were imported to the Endnote reference manager, and 65 duplicate references were identified and excluded. Of the remaining, five articles were excluded by reading the title and

abstract and assessed for relevance to the topic. 23 articles were then assessed for eligibility. Four articles were excluded because they were out of the topic. One new relevant full-text report was identified through forward and backward citation tracking of the articles included in the systematic review. Finally, 20 studies were included. The summary of the research is found in Figure 1.

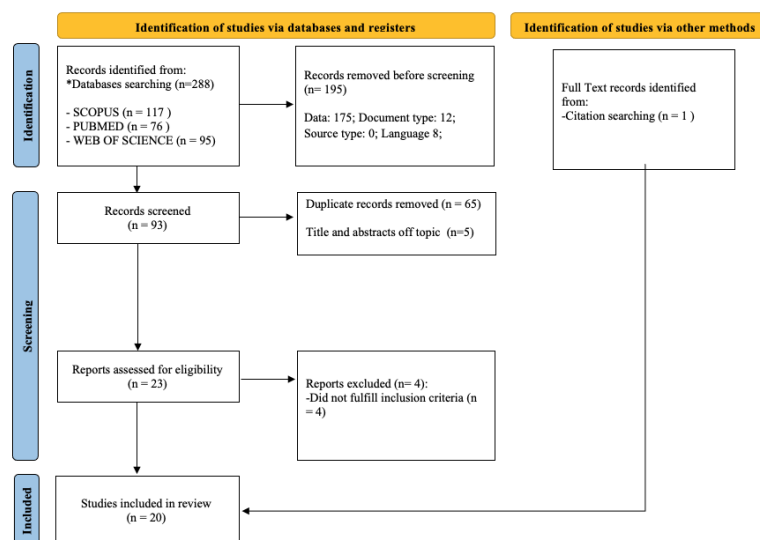


Figure 1. Flow diagram of literature search adapted from PRISMA 2020 (Page et al., 2021)

## Studies' Analysis

The final analysis included 20 cross-sectional studies assessing workplace or environmental exposure to respirable crystalline silica, summarized in Table 1. Key factors analyzed were study year, location, exposure context, and compliance with silica exposure limits. Among the studies, 15 focused on non-mining activities (e.g., cement, construction), while six targeted mining. Only one study evaluated non-occupational exposure (Andraos *et al.*, 2018).

The studies spanned five continents, primarily Asia and Europe, with varying national silica ELV. For instance, OSHA and NIOSH in the U.S. recommend an occupational ELV of 0.05 mg/m<sup>3</sup> over an 8-hour shift, similar to Safe Work Australia and Egyptian standards (Australia, 2020; Mohamed *et al.*, 2018; OSHA, 2019).

However, exposures in many studies exceeded these thresholds. In contrast, some studies reported compliance, such as Rumchev *et al.*, though adverse health effects were still noted (Rumchev *et al.*, 2022). The ACGIH recommends a stricter limit of 0.025 mg/m<sup>3</sup>, adopted in studies from Italy and Vietnam, while EU limits vary, with Greece and Great Britain applying a 0.1 mg/m<sup>3</sup> standard ((ACGIH), 2012; Baldwin *et al.*, 2019; Keramydas *et al.*, 2020).

Silica ELV also differ across regions. For example, Switzerland and India set limits of 0.15 mg/m<sup>3</sup>, while United States of America (USA) standard is 0.05 mg/m<sup>3</sup> (Table 1). Despite compliance in some cases, health risks, including silicosis, were documented at these levels (Dhatrak & Nandi, 2020).

California's OEHHA proposes an ambient limit of 3 µg/m<sup>3</sup>, which Kim *et al.* and Andraos *et al.* highlighted in sanitation and community exposure studies, respectively, underscoring the need for stricter non-occupational assessments (Andraos *et al.*, 2018; Kim *et al.*, 2021).

These findings reveal significant discrepancies in silica exposure standards and compliance globally. The literature suggests that even exposure below permissible ELV poses risks, emphasizing the need for unified regulations and further research into non-occupational exposures.

This investigation revealed that silica levels around facilities often exceed international limits, posing potential health risks, including cancer (Andraos *et al.*, 2018). Non-occupational exposure to silica is a growing concern, with evidence of exposure through natural sources like desert dust, sandstorms, and industrial emissions

affecting nearby populations (Andraos *et al.*, 2018; Bhagia, 2012). Comprehensive studies on non-occupational silica exposure and its health implications remain scarce.

**Table 1.** Summary of selected articles

| References                          | Date | Region      | Design                | Exposure                        | Exposure limit value    | Limit value overtake |
|-------------------------------------|------|-------------|-----------------------|---------------------------------|-------------------------|----------------------|
| (Omidianidost <i>et al.</i> , 2019) | 2019 | Iran        | Cross-sectional study | Occupational/Cement plant       | 0.025 mg/m <sup>3</sup> | Yes                  |
| (Bello <i>et al.</i> , 2019)        | 2019 | USA         | Cross-sectional study | Occupational/Construction       | 0.05 mg/m <sup>3</sup>  | Yes                  |
| (Keramydas <i>et al.</i> , 2020)    | 2020 | Greece      | Cross-sectional study | Occupational/Construction       | 0.10 mg/m <sup>3</sup>  | No                   |
| (Dhatrak & Nandi, 2020)             | 2020 | India       | Cross-sectional study | Occupational/Mining             | 0.15 mg/m <sup>3</sup>  | Yes                  |
| (Cothorn <i>et al.</i> , 2023)      | 2023 | USA         | Cross-sectional study | Occupational/Construction       | 0.05 mg/m <sup>3</sup>  | Yes                  |
| (Park <i>et al.</i> , 2020)         | 2020 | South Korea | Cross-sectional study | Occupational/Construction       | 0.05 mg/m <sup>3</sup>  | Yes                  |
| (Rumchev <i>et al.</i> , 2022)      | 2022 | Australia   | Cross-sectional study | Occupational/Mining             | 0.05 mg/m <sup>3</sup>  | No                   |
| (Mensah <i>et al.</i> , 2020)       | 2020 | Gana        | Cross-sectional study | Occupational/Mining             | 0.05 mg/m <sup>3</sup>  | Yes                  |
| (Koller <i>et al.</i> , 2018)       | 2018 | Switzerland | Cross-sectional study | Occupational/Different sectors  | 0.15 mg/m <sup>3</sup>  | Yes                  |
| (Kim <i>et al.</i> , 2021)          | 2021 | South Korea | Cross-sectional study | Occupational/Sanitation workers | 3 µg/m <sup>3</sup>     | Yes                  |
| (Omidianidost <i>et al.</i> , 2019) | 2019 | Iran        | Cross-sectional study | Occupational/Cement plant       | 0.025 mg/m <sup>3</sup> | Yes                  |
| (Bello <i>et al.</i> , 2019)        | 2019 | USA         | Cross-sectional study | Occupational/Construction       | 0.05 mg/m <sup>3</sup>  | Yes                  |
| (Keramydas <i>et al.</i> , 2020)    | 2020 | Greece      | Cross-sectional study | Occupational/Construction       | 0.10 mg/m <sup>3</sup>  | No                   |
| (Dhatrak & Nandi, 2020)             | 2020 | India       | Cross-sectional study | Occupational/Mining             | 0.15 mg/m <sup>3</sup>  | Yes                  |
| (Cothorn <i>et al.</i> , 2023)      | 2023 | USA         | Cross-sectional study | Occupational/Construction       | 0.05 mg/m <sup>3</sup>  | Yes                  |
| (Park <i>et al.</i> , 2020)         | 2020 | South Korea | Cross-sectional study | Occupational/Construction       | 0.05 mg/m <sup>3</sup>  | Yes                  |

| References                           | Date | Region        | Design                | Exposure                        | Exposure limit value    | Limit value overtake |
|--------------------------------------|------|---------------|-----------------------|---------------------------------|-------------------------|----------------------|
| (Rumchev <i>et al.</i> , 2022)       | 2022 | Australia     | Cross-sectional study | Occupational/Mining             | 0.05 mg/m <sup>3</sup>  | No                   |
| (Mensah <i>et al.</i> , 2020)        | 2020 | Gana          | Cross-sectional study | Occupational/Mining             | 0.05 mg/m <sup>3</sup>  | Yes                  |
| (Koller <i>et al.</i> , 2018)        | 2018 | Switzerland   | Cross-sectional study | Occupational/Different sectors  | 0.15 mg/m <sup>3</sup>  | Yes                  |
| (Kim <i>et al.</i> , 2021)           | 2021 | South Korea   | Cross-sectional study | Occupational/Sanitation workers | 3 µg/m <sup>3</sup>     | Yes                  |
| (Blagrove-Hall <i>et al.</i> , 2021) | 2021 | Canada        | Cross-sectional study | Occupational/Mining             | 0.025 mg/m <sup>3</sup> | Yes                  |
| (Mastrantonio <i>et al.</i> , 2021)  | 2019 | Italy         | Cross-sectional study | Occupational/Construction       | 0.025 mg/m <sup>3</sup> | No                   |
| (Mohamed <i>et al.</i> , 2018)       | 2021 | Egypt         | Cross-sectional study | Occupational/Different sectors  | 0.05 mg/m <sup>3</sup>  | Yes                  |
| (Misra <i>et al.</i> , 2023)         | 2023 | USA           | Cross-sectional study | Occupational/ Mining            | 0.05 mg/m <sup>3</sup>  | Yes                  |
| (Baldwin <i>et al.</i> , 2019)       | 2019 | Great Britain | Cross-sectional study | Occupational/ Different sectors | 0.10 mg/m <sup>3</sup>  | Yes                  |
| (Beaucham <i>et al.</i> , 2018)      | 2018 | USA           | Cross-sectional study | Occupational/ Different sectors | 0.05 mg/m <sup>3</sup>  | Yes                  |
| (Boudigaard <i>et al.</i> , 2022)    | 2022 | Denmark       | Cross-sectional study | Occupational/ Different sectors | 0.025 mg/m <sup>3</sup> | Yes                  |
| (Thai <i>et al.</i> , 2021)          | 2021 | Vietnam       | Cross-sectional study | Occupational/ Cement plant      | 0.025 mg/m <sup>3</sup> | Yes                  |
| (Prajapati <i>et al.</i> , 2021)     | 2021 | India         | Cross-sectional study | Occupational/ Mining            | 0.15 mg/m <sup>3</sup>  | No                   |
| (Andraos <i>et al.</i> , 2018)       | 2018 | South Africa  | Cross-sectional study | Non-occupational                | 3 µg/m <sup>3</sup>     | Yes                  |

This systematic review synthesizes global silica exposure limits, highlighting inconsistencies across countries and within the same nation, where different guidelines are applied without clear criteria (Ehrlich *et al.*, 2021). Although our findings must be considered preliminary because of the broadening of the temporal criterion and possibly of the databases are needed to meet the objective of the final study, our findings have several important public health implications. Analyzing the global data, the ELV are different, and within the same country different guidelines are used without specific criteria. At the same time, workplace silica concentrations frequently exceed occupational ELV, and even low exposures can cause disease. Effective measures, including air monitoring, improved technologies, and collaboration on regulatory frameworks, are essential to mitigate exposure risks (Cothorn *et al.*, 2023; Zhao *et al.*, 2019).

The heterogeneity of the studies is high (Table 2), reflecting variability in legislation, source-specific data, and sampling methods, which complicate comparisons. The quality assessment highlights a lack of standardization in the definition of "environmental exposure," as applied to different work settings with varying conditions.

## Conclusions

Silicosis is a progressive and irreversible, disabling interstitial lung disease caused by inhalation of respirable crystalline silica. The systematic review highlights the importance of guidelines review and controlling the compliance of standard limits of silica dust exposure. Only one study was not conducted in an occupational context and the search included reports from different countries and continents.

Returning to the issue raised in the introduction about the variability of the limit value of silica dust exposure and if these limits are accomplished, the answer is worrying. The data collection shows that although permissible exposure limits are established by regulatory agencies, this does not mean that all workplaces meet these standards. Furthermore, the permissible silica exposure limits are not protecting the health of exposed people. It is important to remember that "safe" levels may not necessarily correspond to the exposure limits allowed. Even low amounts, according to some studies reviewed, can have long-term adverse effects on one's health. As such, every effort should be made to limit exposure.

Targeted prevention requires a deeper comprehension of the influencing factors and social or country context. These results opened our eyes to what needs to be improved. All companies need to be systematically informed about occupational health risks, field inspections must be consistent.

**Table 2.** Risk of Bias Assessment of observational studies (ROBINS E-tool)

| Study                                  | Risk of bias domains |      |      |               |               |     |      | Overall |
|----------------------------------------|----------------------|------|------|---------------|---------------|-----|------|---------|
|                                        | D1                   | D2   | D3   | D4            | D5            | D6  | D7   |         |
| (Omidianidost, Gharavandi et al. 2019) | Low                  | High | High | Low           | Low           | Low | High | Low     |
| (Bello, Mugford et al. 2019)           | Low                  | Low  | Low  | Low           | Some concerns | Low | Low  | Low     |
| (Ehrlich, Noll et al. 2021)            | Low                  | Low  | Low  | Some concerns | Low           | Low | Low  | Low     |
| (Keramydas, Bakakos et al. 2020)       | Low                  | Low  | Low  | Low           | Low           | Low | Low  | Low     |
| (Dhatrak and Nandi 2020)               | Low                  | Low  | Low  | Some concerns | Some concerns | Low | Low  | Low     |
| (Cothorn, Brazile et al. 2023)         | Low                  | Low  | Low  | Some concerns | Low           | Low | Low  | Low     |
| (Park, Hwang et al. 2020)              | Low                  | Low  | Low  | Low           | Low           | Low | Low  | Low     |
| (Rumchev, Hoang et al. 2022)           | Low                  | Low  | Low  | Low           | Some concerns | Low | Low  | Low     |
| (Mensah, Mensah-Darkwa et al. 2020)    | Low                  | High | Low  | Some concerns | Low           | Low | Low  | Low     |
| (Koller, Scholz et al. 2018)           | Low                  | Low  | Low  | Low           | Low           | Low | Low  | Low     |
| (Kim, Kim et al. 2021)                 | Low                  | Low  | Low  | Low           | Low           | Low | Low  | Low     |
| (Blagrove-Hall, Berrault et al. 2021)  | Low                  | Low  | Low  | Some concerns | Low           | Low | Low  | Low     |
| (Mastrantonio, Chivisa et al. 2021)    | Low                  | Low  | Low  | Some concerns | Some concerns | Low | Low  | Low     |
| (Mohamed, El-Ansary et al. 2018)       | Low                  | Low  | Low  | Low           | Low           | Low | Low  | Low     |
| (Misra, Susseil et al. 2023)           | Low                  | High | High | Low           | Low           | Low | High | Low     |
| (Baldwin, Yates et al. 2019)           | Low                  | Low  | Low  | Low           | Low           | Low | Low  | Low     |
| (Beauchamp, King et al. 2018)          | Low                  | Low  | Low  | Some concerns | Some concerns | Low | Low  | Low     |
| (Boudigaard, Hansen et al. 2022)       | Low                  | Low  | Low  | Low           | Low           | Low | Low  | Low     |
| (Thai, Bernalik et al. 2021)           | Low                  | Low  | Low  | Low           | Some concerns | Low | Low  | Low     |
| (Prajapati, Mishra et al. 2021)        | Low                  | Low  | Low  | Some concerns | Low           | Low | Low  | Low     |
| (Andraos, Utambe et al. 2018)          | Low                  | Low  | Low  | Low           | Some concerns | Low | Low  | Low     |

Domains:  
D1: Bias due to confounding.  
D2: Bias arising from measurement of the exposure.  
D3: Bias in selection of participants into the study (or into the analysis).  
D4: Bias due to post-exposure interventions.  
D5: Bias due to missing data.  
D6: Bias arising from measurement of the outcome.  
D7: Bias in selection of the reported result.

Judgement:  
High  
Some concerns  
Low  
No information



and regular, and health surveillance of all exposed workers must be implemented regularly. To do this, efforts must be taken to measure worker exposure to silica and ensure that it is below the permissible exposure level. Employers must take preventive action to decrease exposure if workers are exposed to silica. This can entail implementing dust-control measures (such as ventilation or water), regulating employees' time in dusty environments, or supplying respirators. Health education and the implementation of efficacy and safety of personal and environmental protection equipment must be provided for a better future.

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# A RELAÇÃO DOSE-RESPOSTA NA EXPOSIÇÃO A RUÍDO OCUPACIONAL: A DISTORÇÃO NA QUANTIFICAÇÃO DA DOSE QUE INDUZ A COMUNIDADE MÉDICA EM ERRO

## DOSE-RESPONSE RELATIONSHIP IN OCCUPATIONAL NOISE EXPOSURES: THE DISTORTED QUANTIFICATION OF DOSE THAT MISINFORMS THE MEDICAL COMMUNITY

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### Abstract

**Background:** One of the foundational principles of Medical Sciences is the Dose-Response relationship. When occupational noise is measured, this corresponds to quantifying the Dose. In Portugal, noise is regulated by DL 9/2006 (RGR) which describes the methodologies to be used when quantifying noise levels. **Objective:** To demonstrate how RGR-imposed methodologies are misleading the medical community as to the amount of Dose received and, consequently, compromising the investigation and evaluation of clinical Responses. **Methods:** High resolution noise measurements were continuously acquired during 7 days in a workplace. Data was analysed with RGR methodologies and compared to more modern and scientifically robust methodologies. **Results:** A total of 2022 10-minute recordings were collected, two of which were selected for presentation herein. As per the RGR-imposed methodologies, these two samples reflect similar acoustic environments since both exhibit an overall, audible noise level of 28 dBA. Physical reality, however, demonstrates that these two samples have significantly different acoustic environments, one of 89 dB and the other 47 dB. **Conclusion:** The medical community is being misinformed by the RGR regarding the amount of Dose that workers receive. Consequently, the investigation into potential clinical Responses (health complaints) is frequently deemed (erroneously) to be unnecessary.

**Keywords:** Infrasound, Low frequency noise, A-weighting, Noise-induced pathology, Health complaints.

### Resumo

**Introdução:** Um dos princípios fundamentais das Ciências Médicas é a relação Dose-Resposta. A medição do ruído ocupacional corresponde à quantificação da Dose. Em Portugal, o ruído é legislado pelo DL 9/2006 (RGR) que descreve as metodologias para a quantificação do ruído. **Objetivo:** Demonstrar como as metodologias impostas pelo RGR estão a induzir a comunidade médica em erro quanto à quantidade de Dose recebida e, consequentemente, comprometendo a investigação e avaliação da Resposta clínica. **Métodos:** Foram efetuadas medições contínuas de ruído em alta resolução durante 7 dias num local de trabalho. Os dados foram analisados com as metodologias RGR e comparados com metodologias cientificamente mais robustas. **Resultados:** Das 2022 gravações de 10-minutos recolhidas, duas foram selecionadas para apresentação. De acordo com as metodologias impostas pela RGR, os dois ambientes acústicos são iguais porque ambos apresentam um nível de ruído global audível de 28 dBA. A realidade física, no entanto, demonstra que estes ambientes acústicos são significativamente diferentes, apresentando um 89 dB e o outro 47 dB. **Conclusão:** A comunidade médica está a ser mal informada pelo RGR relativamente à quantidade de Dose que os trabalhadores recebem. Como consequência, a investigação da potencial Resposta clínica (queixas de saúde) é frequentemente considerada desnecessária.

**Palavras-Chave:** Infrassons, Ruído de baixa frequência, Ponderação A, Patologia, Queixas de saúde.

### Introduction

Within Medical Sciences, noise is classified as a *physical* agent of disease, in contrast to biological, chemical or psychosocial agents of disease. As such, noise exposures are comparable to exposures to other physical agents of disease, such as vibration and electromagnetic radiation. The Dose-Response relationship in Medical Sciences is of foundational importance, applicable to exposures to poisons, medications and any type of agent

that can impact human health. For noise exposures, the Dose-Response relationship was defined many decades ago, to prevent hearing impairment and deafness in noise-exposed workers (for example, OSHA, 2025 and EASHW, 2025). Today, occupational noise exposures are limited by values expressed in dBA (A-weighted decibels).

The dBA is a measure of the audible noise in the environment that can potentially cause hearing impairment, depending on exposure time. The “A” refers to the application of the A frequency-weighting filter, or A-weighting, which is used because it simulates the variability of human hearing. When noise is measured linearly (i.e., with no filter or unweighted), noise levels are expressed in dB. The dBA metric has since expanded into the realm of Public Health, within the context of environmental noise exposures, such as from urban, recreational or industrial sources. In occupational settings, the act of measuring noise is equivalent to quantifying the Dose of the agent of disease. The corresponding clinical Response is usually assessed through audiograms which evaluate the auditory function in noise-exposed workers. Professional deafness is legally established at the 4000 Hz band (or notch) of the audiogram.

In Portugal, the legislative document DL 9/2007 (Ministério do Ambiente, 2007), also known as the *Regulamento Geral do Ruído* (RGR) stipulates the methodologies that must be used when measuring noise levels, in both occupational and environmental settings. The stipulations in this legislative document are similar to those found in most other EU and non-EU countries. For example, in New Zealand the document is called SR1995/167 (Ministry of Labour of New Zealand, 1995); in the United Kingdom it is known as UKSI 1989 No. 1790 (HSE, 1989); and in Estonia it is the RTI, 05.12.2018, 12 (Ministry of Social Affairs of Estonia, 2007). These methodologies, which are predominantly based on the dBA metric, effectively exclude the large portion of the acoustic environment that does not cause classical hearing impairment (as measured through audiograms). This excluded portion of the acoustic environment is mostly composed of infrasonic (below 20 Hz) and lower-frequency components (below 200 Hz) that are believed (erroneously—see Stepanov (2000), for example) to have no impact on human health.

The goal of this paper is to demonstrate that the noise measurement methodologies imposed by the RGR are, within the context of Medical Sciences, insufficient to properly characterize the Dose of noise to which workers are exposed. This will be achieved by contrasting the legislation-imposed, A-weighted methodology with a more updated and scientific-grade methodology that uses unweighted values and increased temporal and spectral resolutions.

## Materials and Methods

Within the context of a research project, high-resolution acoustic measurements are being conducted in several occupational environments. The methodology and protocols applied to this research project have been previously used in the quantification of infrasound and low frequency noise within environmental settings (Bakker *et al.*, 2022; IARO 2024). Only one prior study in an occupational environment was performed using this methodology (Stefuryn *et al.*, 2024).

In July 2024, Mrs. S (a member of the general public residing in Lisbon, Portugal) contacted these authors and explained that she and her husband were working remotely from home for the past 2 years. They felt they were being exposed to excessive amounts of low frequency noise, emanating from a large supermarket located beneath their apartment building. She expressed concern for their deteriorating health, and she appeared particularly worried about the symptomatology identified in their 3-year-old daughter. Acoustic recordings were conducted within the S Family workplace/residence for 7 continuous days, from 12 July (18:47) until 19 July (19:04).

Acoustic recordings were obtained with the SAM Scribe FS (Full Spectrum) (Model Mk2, Soundscape Analytics, Palmerston North, New Zealand) (Atkinson & Rapley Consulting, 2016; Bakker *et al.*, 2017) which allows for continuous data acquisition of sound down to 0.1 Hz for days, weeks or months. This system comes equipped with two channels (blue and red microphones) and provides sound data via USB to a Windows computer, with a sampling frequency of up to 44.1 kHz. Recordings are saved on a hard drive in non-compressed

.wav file format. GPS information on location is also recorded in the file metadata with a corresponding digital signature. The frequency response curve of the microphone is practically linear in the 1–1000 Hz range (0.5–1000 Hz:  $\pm 0.5$  dB, 1–10 kHz:  $\pm 2$  dB; 10–20 kHz:  $\pm 4$  dB) (Primo, 2016).

Data was processed by Matlab (The MathWorks, USA) using a Class 0, narrow band filter bank in accordance with ANSI® S1.11-2004 and IEC 61260:1995. Data was acquired with a sampling rate of 11.025 kHz including the calibration signal for reference (Calibrator Type I, 1000 Hz/94 dB tone). Calibration was performed at the beginning and end of each recording. Both microphones were installed on tripods approximately 1.5 m above the ground and were fitted with wind shields throughout the entire recording period. The blue microphone was placed in the child's bedroom and red in the workspace/lounge.

After data acquisition, scientific-grade, high-resolution analyses were performed with:

- A temporal resolution of 1-second,
- A spectral resolution of  $1/36^{\text{th}}$  of an octave, and
- Sound pressure level (SPL) expressed in dB unweighted.

The methodology described in the RGR was also informally applied for the purposes of comparison and clarification, using:

- A temporal resolution of 10 minutes,
- A spectral resolution of  $1/3^{\text{rd}}$  of an octave, and
- SPL expressed in dBA.

## Results

A total of 169 hours of data were acquired, corresponding to 2022 10-minute recordings (both microphones). Table 1 summarizes the number of samples obtained per SPL range, expressed in dBA.

**Table 1.** Number and percentage of Samples, per microphone, within specific SPL ranges, expressed in dBA.

|                    | Blue | %  | Red | %  |
|--------------------|------|----|-----|----|
| <b>&lt;30 dBA</b>  | 524  | 52 | 611 | 60 |
| <b>30 - 40 dBA</b> | 375  | 37 | 254 | 25 |
| <b>40 - 50 dBA</b> | 70   | 7  | 110 | 11 |
| <b>&gt;50 dBA</b>  | 42   | 4  | 36  | 4  |

Table 2 shows the same data but for SPLs expressed in dB.

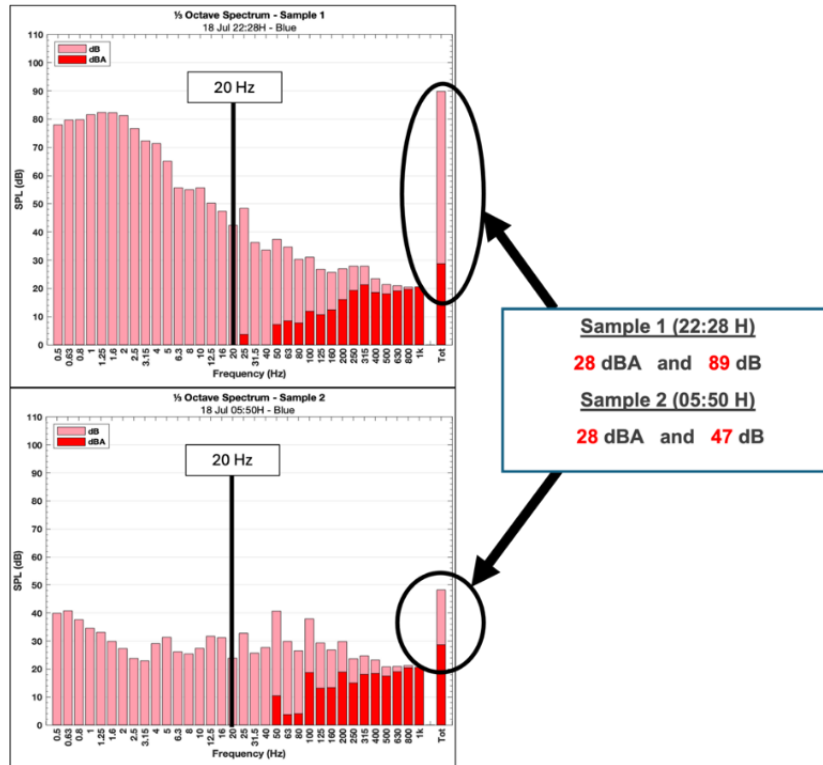
**Table 2.** Number and percentage of Samples, per microphone, within specific SPL ranges, expressed in dB.

|                   | Blue | %  | Red | %  |
|-------------------|------|----|-----|----|
| <b>&lt;40 dB</b>  | 0    | 0  | 0   | 0  |
| <b>40 - 50 dB</b> | 31   | 3  | 24  | 2  |
| <b>50 - 60 dB</b> | 195  | 19 | 186 | 18 |
| <b>60 - 70 dB</b> | 254  | 25 | 252 | 25 |
| <b>70 - 80 dB</b> | 372  | 37 | 372 | 37 |
| <b>&gt;80 dB</b>  | 159  | 16 | 177 | 18 |

Two 10-minute Samples, representative of these recordings, have been selected for presentation herein, both captured with the blue microphone in the child's bedroom at different times of day: Sample 1 starting at 22:28 and Sample 2 at 05:50. These Samples are shown in Figure 1, partially in accordance with RGR methodologies: 10-minute average, spectral resolution of  $1/3^{\text{rd}}$  of an octave, SPLs expressed in dBA (red bars), and with the A-

weighting ensuring that frequencies below 20 Hz will not measurably change the SPL value. Greatly exceeding RGR requirements, Figure 1 also shows the SPLs expressed in unweighted dB (pink bars), with a lower limiting frequency of 0.1 Hz. These values reflect physical reality, i.e., both the audible and inaudible portions of the spectrum.

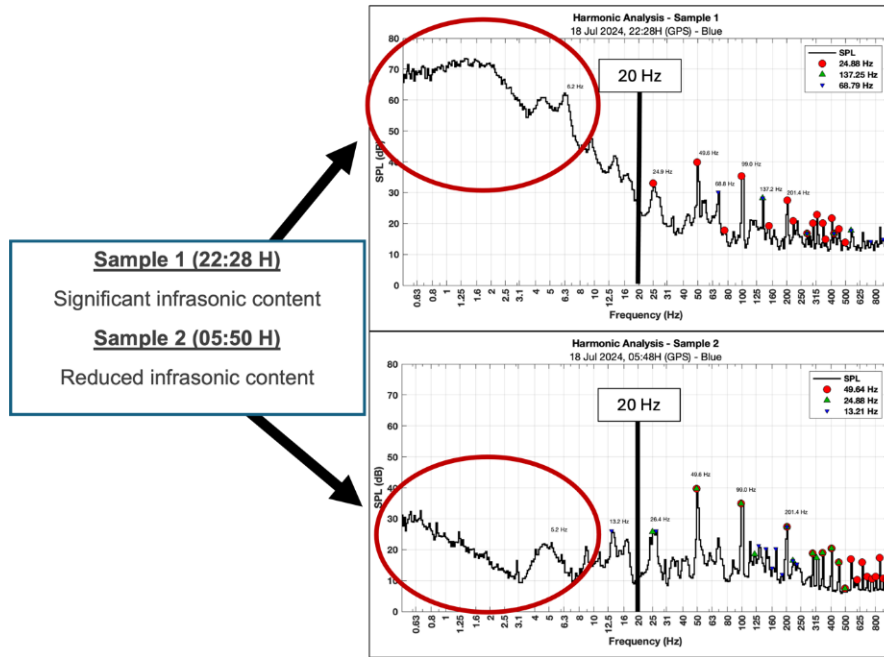
As per the methodology imposed by the RGR, both Samples registered SPLs of 28 dBA. This means that, according to the RGR methodology, the acoustic environment is the same in both Samples. As a result, the RGR methodology stipulates that these two samples reflect equal environments. Consequently, the medical community is informed that there is no acoustical difference in these environments and, therefore, the clinical Response of workers (due to their noise exposure) from these two environments is expected to be similar.



**Figure 1.** Frequency distribution analyses of two acoustic environments, represented as 10-minute average, with a spectral resolution of 1/3<sup>rd</sup> octave. Red bars are SPL expressed in dBA while pink bars are expressed in dB. The bars in black circles represent the overall noise level as expressed in dBA (red) and in dB unweighted (pink).

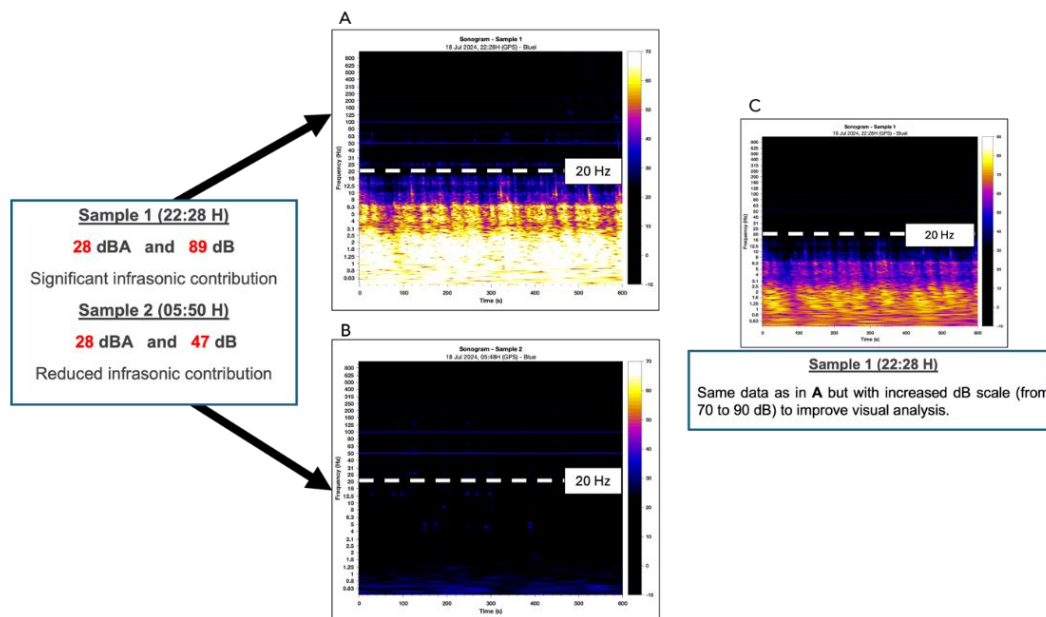
However, when the entirety of the physical soundscape (pink bars in Figure 1) is considered through the removal of the A-weighting (which means non-compliance with RGR methodologies), Sample 1 registers a noise level of 89 dB, while Sample 2 registers 47 dB. Scientifically, then, these acoustic environments are significantly different. The Dose is not the same. The clinical Response of workers in these two environments, due solely to their distinct noise exposures, could reasonably be expected to be substantially different.

Increasing the spectral resolution from 1/3<sup>rd</sup> to 1/36<sup>th</sup> of an octave, and expressing all SPLs in unweighted dB, Figure 2 shows additional acoustic information contained in these two Samples, including the harmonic series analysis.



**Figure 2.** Frequency distribution analyses of the same two acoustic environments shown in Figure 1, represented as 10-minute averages, with a spectral resolution of  $1/36^{\text{th}}$  of an octave, and SPLs all expressed in dB unweighted. The legend in the upper right-hand square indicate the fundamental frequencies of the three most prominent harmonic series identified in each Sample.

Figure 3 shows the sonograms corresponding to each of the Samples. Here, spectral resolution is  $1/36^{\text{th}}$  of an octave, temporal resolution is 1 second and SPLs are expressed in dB (as seen in the colour scale).



**Figure 3.** Sonograms corresponding to Sample 1 (A) and Sample 2 (B) and Sample 1 (C) enlarged.

As expected, the bulk of the acoustic disturbance is occurring below the 20-hertz band. Sample 1 exhibits colour saturation and therefore, a second sonogram is provided (C) where the scale has been increased to improve visual detail.

The sources responsible for these acoustic disturbances have not yet been identified within the context of this ongoing research project.



## Discussion

Using high-resolution analysis of acoustic recordings from occupational environments as a comparison, it is shown that the methodologies imposed by the RGR are insufficient to quantify the Dose of the agent of disease to which individuals are exposed. In fact, RGR methodologies deem two very distinct, and significantly different, acoustic environments as *the same*. The Medical Community is then informed of this scientific fallacy and will expect to see *the same* Response in workers from these significantly different environments.

More egregious is the specific situation shown here: A Dose of 28 dBA would not raise any suspicion of excessive noise-exposure, nor would it raise any concern regarding the risk for hearing impairment. Therefore, the medical community would not see any need to clinically investigate the reported health complaints in association with excessive exposures to the acoustically aggressive environments, as represented by Sample 1. In fact, most scientists in this area are still grounded in the scientific fallacy that “what you can’t hear can’t hurt you.” Indeed, the RGR methodologies are based on this exact, false premise.

Many legislative documents have tried to ‘deal with’ the issue of infrasonic and lower frequency exposures (for example, Ministry for the Environment of Denmark, 2019; Noise Working Group (UK), 1997; Ministry for Social Affairs of Estonia, 2002), although to date, and to these authors’ knowledge, only the Russian Federation has properly legislated permissible exposure levels for infrasonic exposures, in both occupational and environmental settings (Stepanov, 2000). The dBC-dBA measure (SPL in dBC minus the SPL in dBA) was devised to evaluate the extent of these lower frequency components that may be present in the environment. However the C-weighting only maintains a zero weighting down to 100 Hz. Below that range, the C-weighting also introduces an increasing de-weighting of the SPLs (ISO, 2007). Another attempt to ‘deal with’ this type of acoustic pollution was the implementation of the G-weighting. This filter only provides unweighted SPL values at two discreet points of the spectrum: at 10 Hz and at 31.5 Hz (ISO, 1995). Many, if not all, of the frequency-weighting filters are based on the (erroneous) notion that the acoustical environment has to be ‘heard,’ or ‘perceived,’ for it to be harmful. Their ultimate purpose is to reduce the importance of the numerical values for SPLs, as per human perception. When no weighting of any kind is applied to the acoustical data, then a more realistic understanding of the physical environment can be achieved—numerical values of SPL are taken as they exist in the soundscape, and are not altered, or distorted, by weighting systems.

Increasing the spectral resolution from  $1/3^{\text{rd}}$  of an octave to  $1/36^{\text{th}}$  of an octave allows for a more in-depth understanding of the soundscape. This is akin to dividing the meter stick from decimetres into millimetres which, in turn, allows for the measurement of smaller objects. The same is achieved when the segmentation of the spectrum is increased to  $1/36^{\text{th}}$  of an octave. Without the coarse segmentation of  $1/3^{\text{rd}}$  octave, a more detailed analysis of the environment is possible and, as a result, a truer picture of acoustical events is attained. Acousticians would resort to using (Fast) Fourier Transforms (FFTs) to provide detailed analysis when tonality is suspected but, even here, the spectral resolution is rarely chosen to match that of  $1/36^{\text{th}}$  octave, narrow-band filtering at the lowest frequencies, as shown in the analyses herein.

In addition to considering the unweighted SPL values with increased spectral resolution—from  $1/3^{\text{rd}}$  to  $1/36^{\text{th}}$  of an octave—the temporal resolution of these measurements was also increased. The sonograms capture 1-second averages instead of the 10-minute averages shown in the  $1/3^{\text{rd}}$ -octave spectra. The increased spectral resolution and temporal resolution allows for the identification of harmonic series whose fundamental frequency can often be contained within the infrasonic ranges. These would be excluded from capture if the A- C- or G-filters were used. They would be diluted by the temporal resolution of 10-minute averages, and they would be invisible if the  $1/3^{\text{rd}}$ -octave resolution were used.

## Conclusions

The methodologies imposed by the RGR in Portugal (and other similar legislation in other countries) correspond to specifications that were well defined by the limits of the technology almost a century ago. Today, far more sophisticated, scientific-grade characterization of acoustic environments is possible. It is time for these new advances to be incorporated into legislation that is chartered to protect human populations from excessive

acoustical aggressors. These authors urge the medical community to re-evaluate their position on accepting noise levels (i.e., quantification of the Dose) obtained through methodologies that are many decades out of date and do not comply with the Scientific Method.

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## GOOD PRACTICES IDENTIFIED IN THE LITERATURE TO OPERATIONALIZE INTERVENTIONS AIMED AT PREVENTING AND MANAGING PSYCHOSOCIAL RISKS DIAGNOSED BY COPSOQ III

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**Abstract:** Exposure to psychosocial risks at work, resulting from inadequate working conditions, negatively affects people's well-being in organizations, often extending to the family dimension of workers' lives. The Copenhagen Psychosocial Questionnaire (COPSOQ) has been widely used to identify organizational psychosocial risks. Its medium version aims to respond to new trends in the world of work, which makes it suitable for diagnosing psychosocial risks in organizations. Transposing diagnosis into intervention, however, can pose some difficulties for HR managers in terms of what kind of practices can be structured to reduce and/or eliminate these risks. This paper aims to present good practices identified in literature for preventing and managing the 31 risks divided into seven domains evaluated by COPSOQ III, medium version. It serves as a tool for effective interventions that promote employee well-being in the organizational context.

**Keywords:** Organizational interventions; Occupational Psychology; Risk management; Employee well-being.

### Introduction

The work environment has evolved significantly, impacting the health and well-being of employees (Schulte *et al.*, 2019). Psychosocial risks arise from the organization of work and the social context (Leka *et al.*, 2017) and affect the work's well-being and the employee's physical and mental health (Fernandes & Pereira, 2016). Human Resources Management (HRM) should prioritize preventing these risks and communicating safe practices (Silva & Azevedo, 2023). Many organizations struggle to implement effective action plans beyond mere legal compliance in assessing psychosocial risks (Di Tecco *et al.*, 2023).

Various instruments assess psychosocial risks (e.g., JCQ; ERI), but the Copenhagen Psychosocial Questionnaire (COPSOQ) stands out due to its systematic approach (Fernandes & Pereira, 2016; Cotrim *et al.*, 2022). This instrument will guide our recommendations for interventions addressing workplace psychosocial risks. We will discuss the seven conceptual domains and 31 dimensions of COPSOQ III, the medium version, and the key consequences of the identified risks for workers and organizations.

This research arises from the implementation of the Copenhagen Psychosocial Questionnaire (COPSOQ) within a private organizational setting and the request of his HR manager to provide him guidelines on measures to deal with the identified risks. Thus, the primary aim is to present measures identified in the extant literature that seek to eliminate or mitigate those risks, thereby fostering employee safety and well-being. Consequently, this research constitutes a comprehensive literature review.

### COPSOQ III Domains and Dimensions: Risks and Risk Management Measures

#### Demands at Work

Demands at work are related to job aspects and require cognitive, physical, or emotional effort (Van den Broeck *et al.*, 2017). This domain includes the Quantitative Demands, Work Pace, Cognitive Demands, and Emotional Demands dimensions.

Quantitative Demands refer to the number of objectives that must be achieved, and they can be evaluated by assessing the discrepancy between the number of tasks and the time available to complete them (Burr *et al.*, 2019). These demands are closely linked to workplace stress (Mette *et al.*, 2018). To alleviate this, short breaks of about ten minutes can help boost energy and reduce fatigue (Sonnentag & Fritz, 2015). Leaders can support

employee well-being by encouraging these breaks (Albulescu *et al.*, 2022). Identifying potential sources of time pressure within the work environment is also essential (Schilbach *et al.*, 2023).

Work pace refers to the speed at which tasks are performed, measuring the intensity of the work (Burr *et al.*, 2019). It can lead to psychological distress, irritability, anxiety, and frustration (Souza & Lisboa, 2005). Besides regular breaks during work and increasing the amount of time taken to perform a given task (DGS, 2021), granting employees greater control over their work and scheduling, particularly during periods of heightened intensity (Moen *et al.*, 2013), can effectively mitigate time-related stress. Production must be sustainable on a social level (Huo *et al.*, 2022). Therefore, organizations should foster a participatory climate (Paškván & Kubicek, 2017) where transparency prevails, and employees' insights are valued in decision-making processes. Another suggestion is to limit supervisor contact with employees after hours, as proposed by a recent EU directive (Mauno *et al.*, 2022).

Cognitive Demands assess an employee's cognitive skills but can exceed human capabilities, negatively impacting cognitive functioning (Couffe & Michael, 2017). To support employees, personalized strategies should be developed, considering the diverse needs of different groups (Meyer & Hünefeld, 2018). Cognitive ergonomics is essential as it aligns the human-machine relationship with cognitive capacities and limitations (Kalakoski, 2014). Additionally, job crafting practices may help mitigate the adverse effects of high work demands on well-being (Hakanen *et al.*, 2017).

Finally, Emotional Demands encompass situations in which employees deal with the feelings and emotions of others, (e.g. colleagues, customers). They are linked to anxiety (Santa Maria *et al.*, 2017), psychological distress (Bültmann *et al.*, 2002), and depression (Madsen *et al.*, 2010), particularly when seen as extra-role (Duarte *et al.*, 2020). To mitigate these effects, workers should be encouraged to express their feelings, while preventive measures and social support from supervisors are essential (Suh & Punnett, 2022). Training programs that build coping skills can also promote a healthy work environment, promoting intrinsic motivation and job satisfaction (Mazzetti *et al.*, 2020).

### **Work Organization and Job Content**

This domain covers Influence at Work, Possibilities for Development, Control Over Working Time, and Meaning of Work.

Influence at Work refers to the extent to which an employee can affect aspects such as work planning and the sequence of tasks (Burr *et al.*, 2019). When employees feel they have little to no influence, they may experience feelings of helplessness and inadequacy (Czuba *et al.*, 2019). The interpersonal influence of subjects can be promoted through communication: a manager open to employees' opinions promotes their sense of influence at work (Tangirala & Ramanujam, 2012) and commits them to the necessary changes. Managers should use downward communication (e.g., newsletters) to inform employees of organizational changes and upward communication (e.g., team meetings) to address their concerns (Gennard & Judge, 2005).

Possibilities for Development refer to viewing tasks as challenges or opportunities for learning, which can foster both personal and professional growth. When individuals lack development opportunities, they may experience apathy, indifference, and powerlessness (Burr *et al.*, 2019). Employees develop their skills through meaningful learning activities and training. Complex jobs create both pressure and opportunities for skill growth, positively affecting organizational productivity. Continuous training and collaborative relationships between colleagues and managers are essential for effective learning in organizations (Russo, 2016).

Control Over Working Time refers to workers' management of breaks and work hours. Empowering workers with flexible hours, autonomous vacation scheduling, and a culture of decision-making can reduce long sickness absences (Albrecht *et al.*, 2020). When employees choose their schedules and breaks, they feel more in control, and organizations should support this autonomy (Wöhrmann *et al.*, 2021).

Meaning of Work involves the purpose of tasks and their contribution to organizational goals (Burr *et al.*, 2019). It can be achieved by equipping workers with skills and varied tasks, and by discussing their aspirations and values (Albrecht *et al.*, 2021). Transformative leadership that prioritizes team dynamics, provides constructive

feedback, and sets clear goals, can help to build a sense of purpose (Steger, 2016). Training for managers on effective communication is also beneficial (Wikaningrum & Yuniawan, 2018). Additionally, supporting social responsibility activities, like volunteering, can enhance employees' sense of meaningfulness in their work (Cycyota *et al.*, 2016).

### **Work-Individual Interface**

This domain covers the dimensions of Commitment to the Workplace, Job Insecurity, Insecurity over Working Conditions, Quality of Work, Work Life Conflict, and Job Satisfaction.

Commitment to the Workplace refers to how committed the employee feels to the organization (Burr *et al.*, 2019). When workers are loyal and committed to the organization, they are less likely to turnover (Aqilah *et al.*, 2023). Favorable working conditions, adequate facilities, and a supportive environment enable employee efficiency and commitment. Regular training initiatives signal organizational support for growth, promoting belonging and loyalty. Competitive salaries also encourage strong work commitment (Rajak & Pandey, 2017).

Job insecurity refers to an employee's fear of termination or uncertainty about reemployment if they lose their job (Burr *et al.*, 2019). This insecurity can lead to lower satisfaction, enthusiasm, focus, and engagement (Stankevičiūtė *et al.*, 2021). Implementing a clear reward and punishment system can create a more equal and harmonious organizational environment, reducing job insecurity (Wang *et al.*, 2020). Praising employees, promoting inclusivity (Yu *et al.*, 2020), and offering salary incentives are beneficial strategies. It's also essential for employees to be able to express concerns about job insecurity, which can be alleviated through psychological counseling and team-building activities (Yu *et al.*, 2021). Leaders should focus on building strong relationships and involving employees in decision-making, enhancing autonomy, and creating an empowering culture that reduces job insecurity (Wang *et al.*, 2020).

Insecurity over Working Conditions covers aspects of insecurity, such as the content of the work performed, changes in working hours, or deterioration in pay (Burr *et al.*, 2019). Training supervisors is crucial for fostering a partnership with employees, which creates a trusting work environment. Additionally, developing organizational resources, improving working relationships, and gaining leadership support can help organizations mitigate the impacts of job insecurity. This, in turn, facilitates employee engagement even amidst unpredictability or threats of job loss (Asfaw & Chang, 2019).

The Quality of Work evaluates an employee's perception of the tasks they perform or the products they produce (Burr *et al.*, 2019). This quality is determined by the specific work functions or activities carried out over a certain period (Raymond *et al.*, 2015). Reflecting on work-related issues can significantly impact positive outcomes and offers various benefits. This reflection can occur individually or collectively and does not necessarily require a lot of time. For instance, a supervisor might encourage team members to identify areas for improvement, allowing them to assess their strengths and weaknesses (Ellis & Davidi, 2005). Engaging in group reflection enhances performance through collaborative discussions on objectives and methods for accomplishing them (Schippers *et al.*, 2014). Transformational leadership may help this process, contributing to better performance and effectiveness (Lai *et al.*, 2020).

Work-Life Conflict (WLC) refers to the impact of work on family life and vice versa. It involves mental and physical energy, time issues, and can significantly affect workers' mental health (Chandler, 2021). Several strategies can help reduce work-life conflict (WLC). For instance, establishing childcare services, such as a nursery within the workplace for employees' children, can be beneficial. Additionally, providing support services for employees who care for elderly individuals and implementing more flexible work arrangements - such as reduced working hours and telecommuting options - can enable employees to spend more time at home without the need for commuting (Guerreiro *et al.*, 2006).

Finally, Job Satisfaction refers to the employee's satisfaction with multiple aspects of the job (Burr *et al.*, 2019). Dissatisfaction can cause stress, negatively affecting mental health (Qiu *et al.*, 2021). Organizations can enhance employees' job satisfaction through several factors, including the treatment of individuals, the nature of job tasks assigned, the quality of interpersonal relationships within the workplace, and the rewards provided for



performance (Spector, 2012). By prioritizing these elements, organizations not only foster a positive work environment but also contribute to their workforce's overall well-being and motivation.

### **Social Relations and Leadership**

It includes the dimensions of Predictability, Recognition, Role Clarity, Role Conflicts, Quality of Leadership, Social Support from Colleagues, Social Support from Supervisor, and Sense of Community at Work.

Predictability reduces uncertainty or insecurity and is achieved when employees receive essential information at the right time (Burr *et al.*, 2019). Its absence can be a source of stress (Schoellbauer *et al.*, 2022). Predictability plays a significant role in fostering creativity within organizations. Positions characterized by moderate levels of predictability are often assessed by supervisors as exhibiting higher creative performance, in contrast to roles marked by either low or excessively high predictability. This occurs because creativity tends to flourish when certain job parameters are established in advance while remaining flexible enough to encourage innovative thinking. To promote a conducive environment for creativity, organizations can implement structured schedules that enable employees to anticipate specific challenges (Caniëls *et al.*, 2022).

Recognition refers to managers' understanding of the effort made by the employee (Burr *et al.*, 2019) and is one of the most important factors for job satisfaction (Thant & Chang, 2021). Companies should motivate their employees by rewarding their efforts, as this helps to value their contributions (Hussain *et al.*, 2019). Adequate salaries, opportunities for promotion, and training are essential for job satisfaction and recognition (Tadia & Singh, 2020). Also, one of the most effective ways to show recognition is through clear communication. Daily expressions of appreciation, personally thanking individuals, using their names, and specifically detailing the actions that merited recognition all reinforce desired behaviors by referring to particular instances. Additionally, sharing the emotions supervisors feel when goals are achieved, collectively thanking the team for their contributions (Harrison, 2020), and fostering trust-based relationships between supervisors and employees (Daniel & Metcalf, 2005) are valuable methods for promoting a culture of recognition.

Role Clarity reflects the employee's understanding of their role at work (e.g., task content, expectations to be met) (Burr *et al.*, 2019). When employees clearly understand their role, they show greater performance and satisfaction (Thangavelu & Sudhahar, 2017). Organizations should provide detailed role descriptions and align them with organizational objectives to improve processes. Recognizing team members' strengths and weaknesses is crucial for task assignment, fostering knowledge, and skill development, thereby optimizing the administrative culture (Samie *et al.*, 2015).

Role Conflicts can relate to the possible conflicting demands innate to a given task or in prioritizing different tasks (Burr *et al.*, 2019), and may lead to lower performance (Tubre & Collins, 2000). To mitigate role conflicts, organizations can redesign roles and adjust policies to give individuals greater control over their work activities (Vanishree, 2014). Job descriptions serve as effective tools for guiding employee performance, and periodic feedback helps employees understand their roles and responsibilities, enabling effective task performance (Swit-sarra, 2021).

The Quality of Leadership assesses the leadership of top management in different domains and contexts (Burr *et al.*, 2019). Toxic leadership decreases employee motivation, creativity, satisfaction, productivity, and commitment, leading to health issues and stress, which harm organizational performance (Rizani *et al.*, 2022). To enhance employee well-being, leadership should foster a supportive environment by promoting respect and equality, implementing anti-abuse policies, and training leaders in communication and conflict resolution. These measures help employees voice concerns and recognize contributions, reducing abusive behavior and encouraging creativity and innovation (Mehraein *et al.*, 2023).

Social support from colleagues, defined as employees' perceptions of receiving assistance from coworkers, is crucial for job satisfaction and serves as a protective factor against workplace bullying and sexual harassment (Burr *et al.*, 2019; Sigursteinsdottir & Karlsdottir, 2022). This dimension is distinct from "horizontal trust," as employees may receive support without necessarily trusting their colleagues. Peer support programs enhance supportive skills and alleviate workplace stress (Agarwal *et al.*, 2020). Additionally, coaching and mentoring

initiatives for workers and supervisors foster supportive relationships within teams and between employees and supervisors (Ashford *et al.*, 2003).

Social support from supervisors, defined as employees' perception of receiving help from their superiors, is crucial for self-rated health (Burr *et al.*, 2019; Schmidt *et al.*, 2018). Leaders should enhance communication skills, adopt active listening, show empathy, and convey messages effectively. Promoting a culture of collaboration and mutual support through team-building activities fosters an inclusive work environment. Furthermore, developing strategies to mitigate conflicts is vital for effectively managing disagreements (Mahmoudian, 2023). Sense of Community at Work is related to employees' feelings of belonging (Burr *et al.*, 2019). When individuals feel excluded in the workplace, their self-efficacy decreases (Waller, 2020). Promoting belonging requires an inclusive culture where individuals excel and contribute to organizational goals (Pless & Maak, 2004). Leadership should be transformative, fostering motivation, intellectual encouragement, and consideration for team members. Leadership development initiatives, such as workshops or coaching sessions, are effective in occupational safety prevention and health issues (Kelloway & Barling, 2010).

### **Social Capital**

This domain refers to characteristics of a social structure, namely networks, norms, and social trust, that facilitate coordination and cooperation, generating mutual benefit (Putnam, 1995). It contains the Vertical Trust, Horizontal Trust, and Organizational Justice.

Vertical Trust relates to employees' trust in their superiors and vice versa (Burr *et al.*, 2019). It indirectly influences performance (Guinot & Chiva, 2019). Supervisors who demonstrate integrity and benevolence earn employees' trust, fostering support. A lack of trust leads to a culture of silence and low psychological safety (Joo *et al.*, 2023). To build trust, leaders should practice open communication, active listening, and constructive feedback. Transparency, rational decision-making, and appropriate emotional expression are crucial. Consistent behavior from supervisors creates a predictable work environment, reducing stress and anxiety (Ramdas & Sumitha, 2023).

Horizontal Trust relates to whether employees trust their colleagues in their daily work. It can be observed through communication (e.g., the possibility to express attitudes and feelings without fear of others' reactions (Burr *et al.*, 2019). Mistrust and lack of reciprocity are linked to health issues (Suzuki *et al.*, 2010). This dimension significantly impacts organizational climate and team learning more than vertical trust (Agbejule *et al.*, 2021). Trust among team members enhances performance and commitment (Barker & Camarata, 1998). Integrative conflict management strategies, which address all parties' concerns and seek commonalities, are most effective in developing trust (Wertheim, 2017).

Organizational Justice concerns how workers are treated, i.e., whether there is justice. It considers the distribution of tasks and recognition, the sharing process, how conflicts are managed, and how employees' suggestions are dealt (Burr *et al.*, 2019). Employees' perceptions of fairness influence job satisfaction, commitment, engagement, and turnover intentions (Bass & Avolio, 2000). Supervisors can address workplace injustice by explaining resource allocation respectfully, allowing employees to share opinions, and implementing fair provisions. Training initiatives to raise awareness of distributive justice can positively impact employee attitudes and behaviors (Abd Elsalam & Abdelmawgoud, 2023).

### **Personality**

The domain highlights personality characteristics strongly related to coping mechanisms in the face of stress, including self-efficacy. Promoting psychological empowerment enhances employees' perceptions of self-efficacy and their affective commitment to the organization (Ruiz-Fernández *et al.*, 2022; Islam *et al.*, 2014). Encouraging employee participation and involvement in organizational decisions positively impacts self-efficacy and performance (Kim & Beehr, 2017).

## Health and Well-Being

It includes Self-Rated Health, Sleep Problems, Stress, Burnout, and Depressive Symptoms.

Self-Rated Health assesses employees' perceptions of their overall health, encompassing physical and emotional aspects (Pavão *et al.*, 2013). To address this, preventive and intervention measures are necessary. Implementing programs to raise awareness about the importance of physical activity is recommended. Occupational gymnastics, which involves workplace exercises, can prevent musculoskeletal injuries and enhance productivity and quality of life (Mendes & Leite, 2008). Ergonomic posture training is also beneficial. Teaching employees proper posture avoids musculoskeletal injuries (Brisson *et al.*, 1999). Additionally, mental health measures are crucial. Creating a safe environment for discussing mental health issues, supporting employees' return after absences, encouraging open communication, and facilitating social activities can improve overall well-being (Public Health Agency, 2014).

Sleep problems, related to sleep quality and interruptions, are linked to increased mortality, morbidity, and workplace accidents (Burr *et al.*, 2019; Watson *et al.*, 2015). Implementing assessment tools like the Pittsburgh Sleep Quality Scale (PSQI) is crucial for identifying sleep issues (Buysse *et al.*, 1989). Departments with significant sleep quality problems should refer employees to sleep medicine specialists. Establishing reasonable work schedules to minimize sleep disruptions benefits health (Takahashi, 2012).

Burnout assesses the employee's levels of physical and mental exhaustion and fatigue (Burr *et al.*, 2019). Burnout evaluates employees' physical and mental exhaustion. It is linked to poor health, reduced productivity, and dissatisfaction in work and personal life (Burr *et al.*, 2019). It can lead to increased work-related conflicts, substance abuse, and, in extreme cases, suicide (Wall *et al.*, 2014). Primary prevention requires awareness of burnout's impact, while addressing high-burnout departments to identify stress triggers is essential (Lima & Dolabela, 2021). Tools like the Burnout Assessment Tool (BAT) can screen for burnout (Schaufeli *et al.*, 2020). Tertiary prevention involves providing psychological support and occupational health consultations for affected employees.

Stress, resulting from prolonged exposure to high-demand levels, can be managed through organizational measures that foster supportive relationships among employees (Burr *et al.*, 2019). Providing workers with control over their tasks enhances job satisfaction and work quality. Effective communication strategies and positive supervision, where information and guidance support the team, can mitigate stress. Adopting flexible working hours, decentralizing decision-making, and encouraging regular medical check-ups are other beneficial strategies (Prasad *et al.*, 2015).

Depressive symptoms, as indicators of depression, include feelings of guilt, worthlessness, diminished self-confidence, impaired reasoning, decision-making, concentration, suicidal thoughts, and changes in sleep and appetite (Burr *et al.*, 2019; WHO, 2023; Khan & Sultan, 2020). These symptoms negatively impact employee and organizational performance (Khan & Sultan, 2020). Workplace interventions are essential for raising awareness and equipping managers to identify signs of depression, such as poor posture, reduced interaction, fatigue, and missed deadlines (Khan & Sultan, 2020). Effective programs can restore workers' health, leading to a more efficient workforce (Adrian & Aseel, 2014). Initiatives like flexible working hours and promoting work-life balance are also beneficial (James & Lea, 2006).

## Discussion

Given the consequences of psychosocial risks, it is essential not only to assess but also to manage these risks to promote the well-being, productivity, and health of employees (Di Tecco *et al.*, 2023).

Various scientifically validated strategies can be adapted to each organization's specific context. Following the implementation of these practices, a phase of monitoring and evaluation is necessary to ensure their effectiveness, identify areas for improvement, verify the achievement of initial objectives, assess the gains and benefits, consolidate the changes, and, where possible, calculate the profitability resulting from these improvements (Antunes, 2023).

## Conclusions

Effective psychosocial risk management practices can significantly reduce costs with absenteeism, errors, and accidents. These practices enhance the organization's attractiveness by positioning it as a good employer, fostering innovation, responsibility, and a future-oriented approach, which benefits the organization's health and well-being, and the broader community (BSI, 2011).

It is important to recognize that managing psychosocial risks is a dynamic and context-dependent process that is constantly evolving (Fernandes & Cotrim, 2023). Reflecting on the insights gained from this research, it becomes evident that the integration of psychosocial risk management into organizational practices is not merely a strategic advantage but a moral imperative. Organizations must recognize the profound impact that prioritizing the psychosocial well-being of their members has on fostering a resilient and thriving future. This commitment to psychosocial health not only enhances the overall organizational culture but also contributes to long-term sustainability and success in an ever-evolving landscape. As organizations navigate the complexities of modern work environments, the prioritization of psychosocial risk management becomes a crucial component in ensuring the well-being of employees and the overall effectiveness of the organization. By embedding these practices into the organizational framework, leaders can create an environment that supports innovation, responsibility, and a proactive approach to health and safety. This holistic perspective underscores the essential role of psychosocial risk management in achieving sustainable organizational growth and community well-being. In addition, and based on our experience, it is evident that while diagnostic procedures are indispensable, it is equally imperative to establish guidelines for sustained intervention. This approach addresses identified risks, particularly considering that certain organizations may lack in-house psychologists to undertake such tasks. A misalignment between the identified issues and the corresponding solutions may undermine the efficacy of the intervention. Our contribution lies in enhancing this process, thus providing significant added value.

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# TEMPO ATÉ À CERTIFICAÇÃO DE DOENÇAS PROFISSIONAIS EM PORTUGAL: ESTUDO RETROSPETIVO NUM CENTRO HOSPITALAR

## TIME UNTIL CERTIFICATION OF OCCUPATIONAL DISEASES IN PORTUGAL: A RETROSPECTIVE STUDY IN A HOSPITAL CENTER

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### Abstract

**Background:** The recognition of an Occupational Disease (OD) in Portugal is a complex and lengthy process. **Objective:** This study evaluated the time elapsed between OD reporting and the decision by the Department of Protection Against Occupational Risks. **Method:** A retrospective cohort study included 561 cases of OD with completed certification processes, analyzing differences across pathology groups, professional categories and sex. **Results:** The median certification time was 235 days, with significant variations among OD groups. Group 5 (Infectious and Parasitic Diseases) had the shortest median response time (201 days), while Group 4 (Diseases Caused by Physical Agents) had a significantly longer response time (678 days;  $p < 0,001$ ). After excluding COVID-19 cases, the median time in Group 5 increased to 315 days, but remained significantly shorter than that of Group 4 ( $p = 0,007$ ). Among professional categories, nurses had the shortest response time (210 days), significantly lower than administrative technicians (371 days;  $p = 0,0008$ ). No significant differences were observed between sex ( $p = 0,430$ ). **Conclusion:** OD certification times in Portugal remain prolonged, with relevant differences across pathology groups. The lack of deadlines and complexity in recognizing certain diseases contribute to delays. Streamlining certification could improve worker protection, health, and productivity.

**Keywords:** Healthcare workers, Certification time, Recognition process.

### Resumo

**Introdução:** O reconhecimento de uma Doença Profissional (DP) em Portugal é um processo complexo e demorado. **Objetivo:** Avaliar o tempo entre a participação de uma DP e a decisão do Departamento de Proteção contra Riscos Profissionais. **Materiais e Método:** Estudo de coorte retrospectivo com 561 casos de DP certificadas, analisaram-se diferenças entre grupos de patologias, categorias profissionais e sexo. **Resultados:** O tempo mediano de certificação foi de 235 dias, variando entre grupos. O Grupo 5 (Doenças Infecciosas e Parasitárias) teve menor tempo de resposta (201 dias), enquanto o Grupo 4 (Doenças Provocadas por Agentes Físicos) apresentou um tempo superior (678 dias;  $p < 0,001$ ). Após excluir casos de COVID-19, o tempo mediano no Grupo 5 aumentou para 315 dias, mas manteve-se inferior ao Grupo 4 ( $p = 0,007$ ). Enfermeiros tiveram menor tempo de resposta (210 dias), significativamente inferior aos assistentes técnicos (371 dias;  $p = 0,0008$ ). Não se observaram diferenças significativas entre sexos ( $p = 0,430$ ). **Conclusão:** O tempo de certificação das DP em Portugal permanece elevado, com diferenças entre grupos de patologias. A ausência de prazos e a complexidade do processo contribuem para a demora. Agilizar a certificação pode melhorar a proteção dos trabalhadores, a saúde e a produtividade.

**Palavras-chave:** Profissional saúde, Tempo certificação, Processo reconhecimento.

## Introdução

É doença profissional (DP) a lesão corporal, perturbação funcional ou doença que seja consequência necessária e direta da atividade profissional exercida pelo trabalhador e não represente o normal desgaste do organismo (DL n.º 503/99).

Em Portugal, tal como noutros países, o processo de reconhecimento de uma DP envolve várias etapas e intervenientes, sendo que um caso suspeito de DP pode ser participado por qualquer médico ao Departamento de Proteção contra Riscos Profissionais (DPRP), acompanhado dos elementos complementares de diagnóstico que estiveram na base da suspeita. No final, toda a informação reunida é avaliada por dois peritos médicos do DPRP, um deles especialista na doença participada, que avaliam, graduam e certificam a existência da doença profissional (European Commission, 2013; Instituto da Segurança Social, 2024).

A lista em que as DP estão definidas, encontra-se dividida em cinco capítulos distintos, sendo eles, patologias provocadas por agentes químicos (Cap.1), do aparelho respiratório (Cap.2), cutâneas ou outras (Cap.3), provocadas por agentes físicos (Cap.4) e, por último, doenças infecciosas e parasitárias (Cap.5) (Decreto Regulamentar n.º 76/2007).

Em diversos países, têm sido identificados atrasos significativos e heterogeneidade nos tempos de resposta ao processo de certificação de DP (Carder *et al.*, 2015). No entanto, este tipo de análise nunca foi realizado no contexto nacional. Neste estudo, analisámos o tempo decorrido desde a participação de uma suspeita de DP pelo Serviço de Medicina do Trabalho, de um Centro Hospitalar português, até à decisão final emitida pelo DPRP. Foi também analisada a forma como o tempo decorrido variava de acordo com os diferentes grupos de DP e categorias profissionais.

Este trabalho visa preencher uma lacuna importante no conhecimento, contribuindo para identificar fatores que influenciam os tempos de resposta e, potencialmente, melhorar a eficiência do processo de certificação em Portugal.

## Materiais e métodos

Foi realizada uma análise retrospectiva observacional que incluiu 561 casos consecutivos de suspeita de DP, participados entre 2004 e 2023, de um Centro Hospitalar Português, com processo de certificação concluído. O objetivo foi analisar o tempo decorrido entre a participação de DP e a decisão final emitida pelo DPRP, comparando as medianas do tempo de resposta (em dias) entre diferentes grupos de doenças profissionais, categorias profissionais e sexo. A análise estatística foi realizada utilizando o *software IBM SPSS Statistics*, versão 30 (IBM Corp., Armonk, NY, USA). As variáveis contínuas foram testadas quanto à normalidade através do teste de Kolmogorov-Smirnov ou Shapiro-Wilk, conforme aplicável. Diferenças entre os grupos foram analisadas com recurso a testes não paramétricos (Mann-Whitney, Kruskal-Wallis). Valores de  $p < 0,05$  foram considerados estatisticamente significativos.

## Resultados e discussão

Foram incluídos 561 casos de DP com processo de certificação concluído, distribuídos entre 2 casos do Grupo 2 (Doenças do Aparelho Respiratório), 7 casos do Grupo 3 (Doenças Cutâneas ou Outras), 108 casos do Grupo 4 (Doenças Provocadas por Agentes Físicos) e 444 casos do Grupo 5 (Doenças Infecciosas e Parasitárias). A maioria dos trabalhadores afetados era do sexo feminino (88,6%). O tempo mediano de resposta à participação de DP foi de 235 dias, variando entre 721 dias para o Grupo 2, 991 dias para o Grupo 3, 678 dias para o Grupo 4 e 201 dias para o Grupo 5 (Tabela 1).



**Tabela 1.** Distribuição dos Casos de Doenças Profissionais por Grupo e Tempo Mediano de Resposta

| Grupo                                           | Casos (n) | %     | Tempo Mediano de Resposta (dias) |
|-------------------------------------------------|-----------|-------|----------------------------------|
| Grupo 2: Doenças do Aparelho Respiratório       | 2         | 0,4%  | 721                              |
| Grupo 3: Doenças Cutâneas ou Outras             | 7         | 1,2%  | 991                              |
| Grupo 4: Doenças Provocadas por Agentes Físicos | 108       | 19,3% | 678                              |
| Grupo 5: Doenças Infecciosas e Parasitárias     | 444       | 79,1% | 201                              |
| Total                                           | 561       | 100%  | 235                              |

Quando comparados os tempos de resposta entre os diferentes grupos de DP, verificou-se que o Grupo 5 apresentou um tempo mediano de resposta significativamente inferior em relação aos Grupos 3 e 4 ( $p < 0,001$ ) e ao Grupo 2 ( $p = 0,04$ ). Por outro lado, não foram identificadas diferenças estatisticamente significativas entre os outros grupos.

Após a exclusão dos casos de COVID-19 do Grupo 5, o tempo mediano de resposta deste grupo aumentou para 315 dias (Tabela 2). Na análise comparativa dos tempos de resposta entre os grupos de DP, já sem os casos de COVID-19, verificou-se que a única diferença estatisticamente significativa ocorreu entre os Grupos 5 e 4 ( $p = 0,007$ ).

**Tabela 2.** Comparação do tempo mediano de resposta entre grupos da lista de DP, excluindo os casos de COVID-19 do Grupo 5

| Grupo                  | Tempo Mediano de Resposta (dias) | IC 95% inferior | IC 95% superior |
|------------------------|----------------------------------|-----------------|-----------------|
| 2                      | 721                              | 348             | 1094            |
| 3                      | 991                              | 536,1           | 1222,76         |
| 4                      | 678                              | 630,76          | 778,97          |
| 5 - excluindo COVID-19 | 315                              | 272,63          | 607,64          |

Foi comparado o tempo mediano de certificação dos casos de COVID-19 participados como DP com o das restantes DP. Esta análise justificou-se pelo facto de a certificação dos casos de COVID-19 ter seguido um processo diferente, predominantemente administrativo, ao contrário das restantes DP.

Observou-se que o tempo mediano de certificação para todas as doenças profissionais, com exceção da COVID-19, foi de 636,5 dias, enquanto para os casos de COVID-19 esse tempo foi significativamente menor, com uma mediana de 197 dias ( $p < 0,001$ ) (Tabela 3).

**Tabela 3.** Comparação dos Tempos de Certificação de DP (COVID-19 vs. Outras DP)

| Grupo     | n   | Tempo Mediano de Resposta (dias) | IC 95%        | p      |
|-----------|-----|----------------------------------|---------------|--------|
| COVID-19  | 429 | 197                              | [170,3–223,7] | <0,001 |
| Outras DP | 132 | 636,5                            | [590,2–682,8] |        |

O tempo mediano de resposta à certificação de DP variou significativamente entre as categorias profissionais analisadas ( $p = 0,004$ ). O maior tempo foi registado nos assistentes técnicos (371 dias), enquanto o menor foi observado entre os enfermeiros (210 dias). As categorias de assistentes operacionais/técnicos auxiliares de saúde



e médicos apresentaram tempos medianos semelhantes (251 dias). Já a categoria de outros profissionais clínicos, que inclui técnicos superiores de saúde e técnicos superiores de diagnóstico e terapêutica, registou um tempo mediano de 264 dias (Tabela 4).

**Tabela 4.** Comparação do tempo mediano de resposta entre categorias profissionais

| <b>Categoria Profissional</b> | <b>N</b> | <b>Tempo Mediano de Resposta (dias)</b> | <b>IC 95%</b>     | <b>p</b> |
|-------------------------------|----------|-----------------------------------------|-------------------|----------|
| AO/TAS                        | 177      | 251                                     | [109,80- 1287,40] | 0,0044   |
| AT                            | 31       | 371                                     | [141,75-1004,50]  |          |
| Enfermeiro                    | 236      | 210                                     | [89,88-1053,38]   |          |
| Médico                        | 77       | 251                                     | [141,50-1266,00]  |          |
| Outros clínicos               | 40       | 264                                     | [129,80-978,0]    |          |

A análise post-hoc demonstrou que a diferença significativa se encontrava na comparação entre os enfermeiros e os assistentes técnicos ( $p=0,0008$ )

Não se verificaram diferenças estatisticamente significativas no tempo de resposta entre sexos ( $p=0,430$ ) (Tabela 5).

**Tabela 5.** Comparação do tempo mediano de resposta entre sexos

| <b>Sexo</b> | <b>n</b> | <b>Tempo Mediano de Resposta (dias)</b> | <b>p</b> |
|-------------|----------|-----------------------------------------|----------|
| Feminino    | 497      | 238                                     | 0,430    |
| Masculino   | 64       | 221,5                                   |          |

Os resultados revelam que o tempo mediano de resposta para a certificação de uma suspeita de DP varia significativamente conforme o grupo de patologias, sendo o Grupo 5 aquele que apresentou o menor tempo de resposta. Verificou-se que mesmo retirando os casos de DP COVID-19 deste grupo, este apresentou menores tempos de resposta que as doenças do Grupo 4, sendo essas diferenças estatisticamente significativas.

O facto de os profissionais de saúde estarem, pela própria natureza da sua atividade, expostos a fatores de risco biológicos, facilita o estabelecimento do nexo de causalidade nas DP pertencentes ao Grupo 5 (Doenças Infecciosas e Parasitárias). Nesses casos, a relação entre a exposição ocupacional e a doença é frequentemente direta e bem estabelecida, como ocorre em infeções por tuberculose ou escabiose adquiridas em ambiente hospitalar (Godfred *et al.*, 2023). Por outro lado, o nexo causal em patologias do Grupo 4 (Doenças Provocadas por Agentes Físicos), nos quais se encontram as doenças músculo-esqueléticas e que no caso da nossa série correspondem a 98% das doenças incluídas neste grupo, é mais difícil de demonstrar, dada a multicausalidade envolvida e a dificuldade em quantificar a exposição específica (Luan *et al.*, 2018; Punnett & Wegman, 2004; Serranheira *et al.*, 2012). Esta complexidade pode justificar, em parte, os desafios no reconhecimento dessas doenças como doenças profissionais.

As doenças musculoesqueléticas representaram em 2023 o diagnóstico clínico mais frequente entre as doenças profissionais certificadas com e sem incapacidade para o trabalho em Portugal (Autoridade para as Condições do Trabalho, 2024), facto que provavelmente também contribui para um maior tempo de espera para certificação das doenças do Grupo 4.

Adicionalmente, a comparação com estudos internacionais revela margem para melhoria no sistema português. Por exemplo, um estudo realizado em Espanha relatou um tempo mediano de certificação de 353 dias para doenças musculoesqueléticas (Pelegrí *et al.*, 2022), valor significativamente inferior aos 678 dias encontrados no nosso trabalho para o Grupo 4, em que 98% das patologias incluídas são musculoesqueléticas. Embora as

categorias analisadas não sejam totalmente equivalentes, esta diferença sugere a necessidade de otimização do processo em Portugal.

O processo de certificação da COVID-19 apresentou um tempo de resposta consideravelmente mais curto em comparação com outras DP. Esta diferença pode ser explicada pelo caráter tendencialmente administrativo do processo de certificação da COVID-19 durante a pandemia. Em contraste, a mediana do tempo de certificação para outras DP foi de 636,5 dias. Estes dados reforçam a ideia de que o tempo de resposta para a certificação de DP em Portugal continua a ser longo, surgindo a necessidade de medidas que possam agilizar o processo e garantir uma resposta mais rápida e eficaz para todas as patologias.

No que diz respeito às categorias profissionais, observou-se que os enfermeiros tiveram um tempo de certificação significativamente mais curto em comparação com os assistentes técnicos. Esta diferença pode ser parcialmente explicada pela maior proporção de DP COVID-19 entre os enfermeiros ( $n=206/236$ ), em comparação com os assistentes técnicos ( $n=13/31$ ). Como já mencionado, a certificação de DP COVID-19 apresentou tempos de resposta mais curtos, o que pode ter influenciado diretamente os resultados para esta categoria profissional.

### Limitações

Este trabalho apresenta algumas limitações que devem ser consideradas. A análise foi realizada com base apenas numa série de casos de um único centro hospitalar, o que pode limitar a generalização dos resultados. Além disso, a natureza retrospectiva do estudo não permite uma avaliação detalhada de todos os fatores que possam ter contribuído para a variação no tempo de certificação. Estudos futuros, multicêntricos e com amostras mais amplas são necessários para confirmar os achados, identificar variações entre diferentes instituições e aprofundar o conhecimento sobre os fatores que influenciam o tempo de certificação de DP em Portugal.

### Conclusões

Verifica-se que as Doenças Profissionais ainda apresentam um tempo de espera longo até ao reconhecimento oficial, e isso pode ser uma das razões para a subnotificação de DP tanto em Portugal como noutros países da Europa (Direção-Geral da Saúde, 2014; Khoe *et al.*, 2024).

É importante refletir e estudar formas de otimizar este processo, sendo que, a digitalização do processo poderia reduzir significativamente o tempo necessário para a submissão da documentação e para o conhecimento do resultado da certificação pela entidade empregadora, pelo médico do trabalho e pelo trabalhador, facilitando a comunicação entre os intervenientes e acelerando o processo de certificação.

Outro ponto que merece atenção é a ausência de um prazo legalmente estipulado para a conclusão do processo de certificação de DP pelo DPRP. Embora existam prazos iniciais para a participação da DP pelo médico do trabalho ou pelo médico assistente e pelo trabalhador, sendo que esta deve ser remetida no prazo de oito dias a contar da data do diagnóstico ou de presunção da existência de doença profissional (DL n.º 98/2009), não há prazos definidos para a avaliação e emissão da decisão final. Este fator pode contribuir para os longos tempos de resposta observados no estudo. A implementação de prazos máximos para a emissão da decisão final poderia agilizar o processo e reduzir o tempo de espera.

Em suma, é importante que o processo de certificação de DP se torne mais célere não só para combater a subnotificação (Direção-Geral da Saúde, 2014; Khoe *et al.*, 2024), mas também porque uma resposta mais rápida permitiria definir estratégias de atuação, alterar métodos de trabalho, proporcionando assim ambientes de trabalho mais saudáveis, prevenindo a doença nos trabalhadores, melhorando a sua qualidade de vida e produtividade (Pereira *et al.*, 2023).

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# SMART TECHNOLOGIES IN HOUSEHOLD SOLID WASTE COLLECTION: REDUCING OCCUPATIONAL RISK FOR COLLECTION WORKERS. A REVIEW.

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## Abstract

**Background:** Household solid waste collection is labor-intensive and high-risk. **Objective:** To describe new technologies reducing occupational risks inherent to this activity. **Methods:** A literature review with (PRISMA) methodology compared the occupational risks solid waste collection workers face in developed and developing nations across Africa, Asia, and Europe that utilize door-to-door waste collection systems and the potential of IoT-based Smart Waste Management Systems to mitigate these risks in household waste collection. The search was carried out through Scopus and Web of Science databases. **Results:** Initially, 2417 items were found in the search databases, of which 24 were included. Door-to-door solid waste collection expose workers to multiple occupational hazards. Implementing IoT-based waste management technologies such as (systems to collect, send, and analyze data from waste collection points with sensors, processors, or communication hardware, presents a promising approach to mitigating these hazards and helping optimize collection routes, reducing physical strain and minimizing direct human contact with waste. However, implementing of these IoT technologies may face challenges, particularly the need to restructure the door-to-door collection system. **Conclusions:** The study highlights the urgent need for innovative solutions to reduce occupational risks and improve working conditions for waste collection workers.

**Keywords:** Occupational Safety, Waste Collection, Musculoskeletal Disorders, Smart Technologies, Occupational Hazards.

## Introduction

The production of waste in various forms solid, gaseous, or liquid, has increased significantly as the population grows, so municipal solid waste collection systems must deal with waste and environmental and esthetic problems (Rajendren *et al.*, 2024). Properly managing the tons of waste generated daily has become one of the most pressing challenges of the 21st century. This increase in waste volume is attributed to the rapid growth of the population and the difficulties associated with waste disposal (Fayomi *et al.*, 2021). By 2050, global waste generation projected to reach an astonishing 3.40 billion tons, which implies a tripling of current levels (Kasa, Silpa, n.d.).

Households are the primary generators of solid waste. Once the waste is placed on the street, the first stage of the collection begins, which requires human labor to remove it. Although waste collection work contributes to public health systems in many countries (*Decent Work in Waste Management*, 2014), workers in this sector, are exposed to various occupational hazards and unsafe working conditions, as well as face social stigma of discrimination due to the nature of their work (World Health Organization., n.d.).

This study compares IoT (Internet of Things) technology with the door-to-door systems in the waste collection sector. First, in a door-to-door system, different types of waste are collected directly from the user's home (Degli Esposti *et al.*, 2023). Workers involved in this method face exposure to several occupational risks, including musculoskeletal disorders, injuries, lacerations from handling waste, and chemical and biological risks (Thakur *et al.*, 2018). Despite the challenges, this method remains vital in many countries, serving as the primary system for managing household waste (Maalouf & Agamuthu, 2023).

The second methodology involves an integrated system model for intelligent waste collection based on IoT (Internet of Things) technology. This system employs sensors installed in waste bins to monitor waste levels and transmits data over the Internet to a central server for processing (Gutierrez *et al.*, 2015). In contrast to traditional methods, it minimizes direct contact between workers and waste, thereby reducing occupational

risks. In fact, a study indicated that just the implementation of solid containers reduced by 70.27% the number of accidents related to sharp materials and falls (Dos Santos *et al.*, 2020). It represents a promising seed of change in the field of waste collection, offering a safer and more efficient alternative, which, in fact, should be further studied in future research as there is currently a gap in this area.

There is a marked difference between these two systems, the door-to-door collection system being the most common form of collection in some countries (Door-to-Door Waste Collection › Evreka, 2022). At the same time, IoT technology is often applied in cities around the world that have adopted the smart city model, corresponding to an urban planning model based on the digitization of services, digitization of processes, and decision-making based on data analysis (I. Shah *et al.*, 2021).

Adopting IoT-based waste collection systems, in cities that rely on door-to-door methods could significantly improve collection workers' working conditions while contributing to broader public health and environmental goals. This approach underscores the potential for technological solutions to transform essential yet hazardous jobs into safer and more sustainable practices and lays the foundation for their adaptation in other cities worldwide.

In brief, the aim of this work is to present a technological alternative to solid waste collection that is currently being tested. These solutions not only help reduce the occupational risks faced by waste collection workers and offer environmental benefits but also prove to be cost-effective in the long run, as the expenses associated with worker illnesses and injuries often exceed the investment in safer and more efficient waste collection systems.

## Materials and Methods

### Search Characteristics

The study used a systematic review methodology PRISMA (Page *et al.*, 2021), while the eligibility criteria for the initial stage included literature published between 2020 and 2024, using predefined keywords to facilitate the search, and only articles in English. The first stage focuses on IoT technology applied to household solid waste collection, specifically Smart Waste Management Systems, such as smart bin sensors, smart trucks, and region-specific smart bins. The selected keywords included: waste collection, waste, intelligence, smart, musculoskeletal disorders, occupational risks, and health.

In the second stage, a literature search was conducted to identify risk factors affecting solid waste collection workers. Keywords used in this stage included: waste collectors, waste, occupational risks, occupational health, occupational hazards, musculoskeletal disorders, and ergonomics.

In the third stage, the reference management software Zotero (Zotero | *Your Personal Research Assistant*, n.d.) was used to download the databases and conduct an initial screening based on the titles and objectives of the articles. Only those articles meeting the predefined inclusion criteria were selected for further analysis.

### Characteristics of Accepted Studies

In the first stage, the search focused on studies related to IoT-based smart waste management systems. Research articles on IoT applications in smart cities were analyzed, particularly those examining the design of smart waste management systems for household solid waste collection using IoT technology. In the second stage, the focus shifted to studies on occupational risks among waste collection workers engaged in physically demanding tasks, such as door-to-door collection. This analysis aimed to establish a reference for the occupational hazards these workers face.

The databases consulted were Scopus and Web of Science; in each database, the filters used were publication year (between 2020 and 2024), type of document (article), type of source (journals), and language (English). The research was carried out from 24 November to 15 December 2024.

The search strategy for IoT includes the combination of the following keywords: ("waste collection" OR waste) AND (intelligence OR smart) AND ("musculoskeletal disorders" OR "occupational risk" OR health) AND NOT "e-waste".

Likewise, the search strategy for the research on occupational risk factors in SWC (Solid waste collection) was: ("waste collectors" OR waste) AND ("occupational risk" OR "occupational health" OR "occupational hazard") AND ("musculoskeletal disorders" OR ergonomics).

### Study Records

Data management was carried out by directly downloading information from electronic databases into the reference manager Zotero (Zotero | Your Personal Research Assistant, n.d.), facilitating organization throughout the screening process. The information was transferred to an Excel matrix for further analysis after the screening. In the initial stage, information from electronic databases was imported into Zotero, and a preliminary screening of article titles was conducted to determine their alignment with the study's objectives. The abstract was reviewed if there were doubts about the article's suitability for inclusion. Subsequently, in the second stage, the extracted data were imported into the Rayyan software (Rayyan | Home, n.d.) for duplicate detection, where duplicate articles were screened and removed. The selected articles were then re-imported into the Zotero reference manager. After the initial screening stage, the subsequent evaluation was conducted based on the eligibility criteria. Relevant information was then extracted from the articles to complete a matrix.

Subsequently, an Excel matrix was created, with each row representing a different article and each column corresponding to a parameter or variable extracted from the articles. Information extraction was performed using the SciSpace software (AI Chat for Scientific PDFs | SciSpace, n.d.), followed by manual verification of the content by reading the sections of the articles.

Therefore, the accepted articles were those that *met all* these minimum criteria:

- Studies about IoT include (Smart Waste Management Systems: Smart Bin Sensors, Smart Truck, and Region Smart Bin).
- Waste management using IoT using bin based on IoT.
- Smart cities with IoT models of waste management.
- Studies about occupational hazards and risk factors related to SWC. Articles that were focused on other subjects as following were excluded:
- Articles related to evaluating attitudes, risk behavior, and practices of workers; perception of workers (there were no available risk assessment tools); surveys about health and safety programs.
- Articles related to child waste workers.
- Studies focused on recycling plants in informal sectors where the door-to-door collection system does not apply.

### Results

The selection process results are shown in Figure 1. Initially, 2417 items were found in the search databases. Then, with the application of search filters such as date, document type, source type, off-topic, and language restrictions, 2372 articles were excluded. Additionally, 13 duplicate records were also removed.

In the screening phase, of the remaining 32 articles, four were excluded for being off-topic (not related to the door-to-door waste collection system and not focused on IoT in the waste collection area), leaving 28 articles for retrieval. Among these, two articles were not available online. In the final step, one article was excluded because the study was unrelated to the scope of the research in waste collection, and one more was excluded as it did not align with the review objectives.

Therefore, 24 articles were identified as relevant publications for the present study; of these, 17 pertain to smart technologies proposed in SWC, and seven focus on risk factors affecting solid waste collection workers.



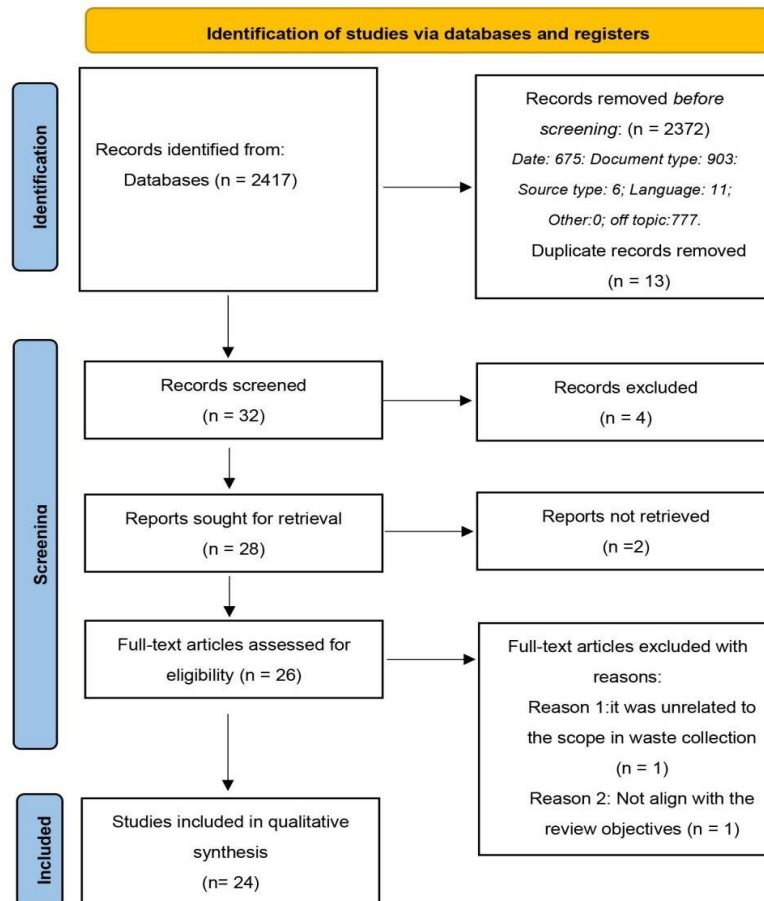


Figure 1. PRISMA 2020 Flow Diagram of the research (Page *et al.*, 2021).

## Study characteristics

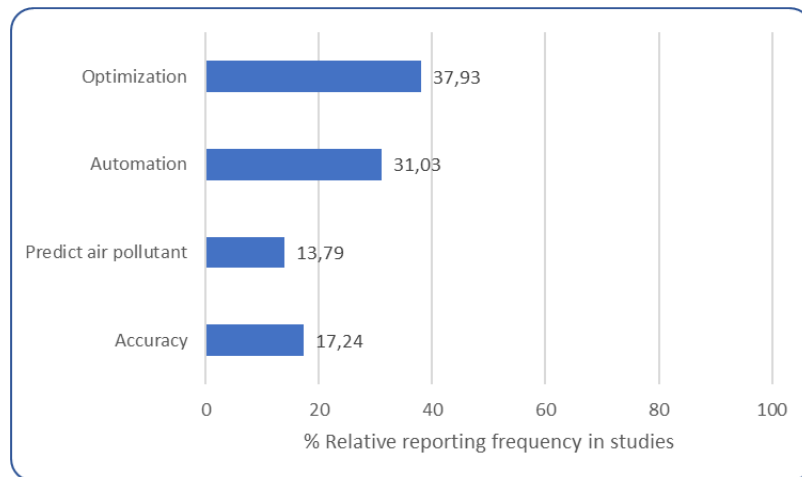
### Smart technologies in solid waste collection system

The selection process results are shown in Table 1. In terms of geographical distribution, most studies were conducted in Asia (94.12%) and Africa (5.88%). The main smart devices used in waste management for smart cities were IoT-based smart bins with fill-level sensors for garbage management (Abba & Light, 2020; Abidin *et al.*, 2022; Abuga & Raghava, 2021; Addas *et al.*, 2024; Bhowmik *et al.*, 2020; A. Hussain *et al.*, 2020, 2020; I. Hussain *et al.*, 2024; Joshi *et al.*, 2022; Lama & Karmakar, 2024; Okubanjo *et al.*, 2024; Ramson *et al.*, 2021; Sung *et al.*, 2022; Vishnu *et al.*, 2021; Zhang *et al.*, 2020), which allow real-time monitoring of bin fullness levels and the creation of optimized daily collection routes, likewise IoT-based camera sensors for data collection (Al Duhayyim *et al.*, 2022). Weight sensors for waste measurement (I. Hussain *et al.*, 2024; Zhang *et al.*, 2020) and real-time communication between waste bins and collection vehicles (Abba & Light, 2020; Addas *et al.*, 2024; Bhowmik *et al.*, 2020; I. Hussain *et al.*, 2024; Ramson *et al.*, 2021; Sung *et al.*, 2022; Zhang *et al.*, 2020).

With respect to the implementation of IoT-based waste management, the research findings were categorized into the following subjects:

- **Accuracy:** Effectiveness and functionality of smart bins.
- **Air pollutant prediction:** Effective measurement of air pollutants.
- **Automation:** Facilitates real-time monitoring of garbage bin levels and minimizes human contact with waste.
- **Optimization:** Improves sorting efficiency.

The relative frequency results for these subjects found in the studies are presented in Figure 2. It is observed that most studies reported findings about optimization (37.96%) and automation (31.03%).



**Figure 2.** Results obtained from the implementation of IoT-based waste management.

**Table 1.** Smart technologies proposed in solid waste collection.

| Title/Reference                                                                                                                                                   | Country      | Technology used                                                           |                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                   |              | Device/technique                                                          | Characteristics                                                                                                                                                                                                                 |
| Waste management and prediction of air pollutants using IoT and machine learning approach.<br>(A. Hussain <i>et al.</i> , 2020)                                   | Pakistan     | Smart bin for garbage management                                          | -Machine learning models for predicting bin status.<br>-Deep learning for forecasting air pollutants.                                                                                                                           |
| Smart garbage bin based on AIoT.<br>(Sung <i>et al.</i> , 2022)                                                                                                   | Taiwan       | -A prototype smart garbage.                                               | -A Bluetooth signal tracks the smart garbage bin's location                                                                                                                                                                     |
| Artificial Ecosystem-Based Optimization with an Improved Deep Learning Model for IoT-Assisted Sustainable Waste Management.<br>(Al Duhayyim <i>et al.</i> , 2022) | Saudi Arabia | -IoT-based camera sensors for data collection, model AEODL-SWM technique. | Microcontroller for data processing                                                                                                                                                                                             |
| An Intelligent Waste Removal System for Smarter Communities.<br>(Zhang <i>et al.</i> , 2020)                                                                      | China        | -Smart bin<br>-Weight sensor<br>- RRT algorithm.<br>-ROS operating system | -Microcontroller for data processing<br>-Weight sensor for measuring garbage weight.<br>-Algorithm for path planning in waste collection vehicles.<br>- ROS operating system for intelligent waste disposal process automation. |
| Smart trash bin for management of garbage problem in society.<br>(Abidin <i>et al.</i> , 2022)                                                                    | Indonesia    | -Smart bin<br>- (WCVs)                                                    | -Full bins notify cleaners via Telegram messages.<br>-The lid opens automatically when approached.                                                                                                                              |
| Smart bin and IoT: a sustainable future for waste management system in Nigeria.<br>(Okubanjo <i>et al.</i> , 2024)                                                | Nigeria      | -Bin with ultrasonic sensors.<br>-Wi-Fi module for data transmission.     | Ultrasonic sensors for object detection and waste level monitoring.                                                                                                                                                             |
| Secure waste collection approach for smart cities.<br>(Lama & Karmakar, 2024)                                                                                     | India        | -AVISPA tool<br>-Smart bin                                                | -AVISPA for security analysis.                                                                                                                                                                                                  |

| Title/Reference                                                                                                                                                     | Country       | Technology used                                     |                                                                                                                                                        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                     |               | Device/technique                                    | Characteristics                                                                                                                                        |
| Design and development of smart Internet of Things-based solid waste management system using computer vision.<br>(Mookkaiah <i>et al.</i> , 2022)                   | India         | - (CNN) for waste classification                    | Machine learning techniques: regression, classification, clustering, correlation rules.                                                                |
| Real-time smart garbage bin mechanism for solid waste management in smart cities.<br>(Abuga & Raghava, 2021)                                                        | India         | -Smart bin                                          | -Smart Garbage Bin Mechanism.<br>- Net Logo platform                                                                                                   |
| Real time monitoring of solid waste with customized hardware and Internet of Things.<br>(Joshi <i>et al.</i> , 2022)                                                | India         | -Smart bin<br>-Ultrasonic sensors                   | - Garbage levels are indicated by colored lights.<br>-Sensor nodes communicate data to the cloud server.                                               |
| IoT-Enabled solid waste management in smart cities.<br>(Vishnu <i>et al.</i> , 2021)                                                                                | Not available | -Smart bin                                          | -Public Bin Level Monitoring                                                                                                                           |
| IoT (Internet of Things) -Based smart garbage management system: a proposal for major cities of Bangladesh.<br>(Bhowmik <i>et al.</i> , 2020)                       | Bangladesh    | -Smart bin                                          | - Real-time data transmission to central server.<br>- Smart bins will have sensors for garbage level detection.                                        |
| IoT-Based framework for smart waste monitoring and control system: a case study for smart cities<br>(Abba & Light, 2020)                                            | Not available | -Smart bin.<br>-Ultrasonic sensors                  | -Ultrasonic sensors detect garbage levels in bins.<br>-IoT-based Arduino microcontroller for waste monitoring.                                         |
| Waste management 2.0 leveraging internet of things for an efficient and eco-friendly smart city solution.<br>(Addas <i>et al.</i> , 2024)                           | Pakistan      | - Smart bin.<br>-Ultrasonic Sensors.                | -Ultrasonic Sensors: to measure the distance to the waste within the garbage bins.<br>-Dynamic route optimization algorithms for collection efficiency |
| An IoT-based bin level monitoring system for solid waste management.<br>(Ramson <i>et al.</i> , 2021)                                                               | Not available | - (BLMU).<br>- Smart graphical (SG) user interface. | -(BLMU) for trash bins<br>-SG user interface for monitoring.                                                                                           |
| An internet of things based smart waste system.<br>(Jasim <i>et al.</i> , 2021)                                                                                     | Iraq          | -Wi-fi Micro controller.<br>- Ultrasonic sensors    | -Ultrasonic sensors for waste level measurement.                                                                                                       |
| Smart city solutions: comparative analysis of waste management models in IoT-enabled environments using multiagent simulation.<br>(I. Hussain <i>et al.</i> , 2024) | Qatar         | -Smart bin<br>-Ultrasonic and weight sensors        | - Ultrasonic and weight sensors.<br>- Real-time monitoring with IoT-connected waste bins.                                                              |

Abbreviation: IoT: Internet of things; ROS: Route operation system; RRT: Rapid exploration of random trees; WCVs: Waste collection vehicles. CNN: Convolutional Neural Network; BLMU: Bin Level Monitoring Unit. AVISPA: Automated Validation of Internet Security Protocols and Applications; AEODL-SWM: artificial ecosystem-based optimization with an improved deep learning model for IoT-assisted sustainable waste management.

### Occupational Safety and Health Assessment of Solid Waste Collection Workers

Studies in occupational risks among solid waste collection workers are summarized in Table 2. The studies showed waste collection workers were exposed to several occupational risk factors. First, regarding ergonomic risks, the tasks performed by the workers were categorized as follows: repetitive tasks (Hossain *et al.*, 2024;

Kaphle *et al.*, 2024; Ziaei *et al.*, 2019), lifting, loading, and carrying waste (Elsayed Farid Amr & Abdel Malek Hussein, 2021; Sangkham *et al.*, 2021; Ziaei *et al.*, 2019), pulling and pushing (Rossi *et al.*, 2022; Ziaei *et al.*, 2019). Additionally, awkward postures were analyzed in two studies (Kaphle *et al.*, 2024; Van Nguyen *et al.*, 2020). These factors could be directly associated with the musculoskeletal disorders (MSDs) reported in all studies. Studies indicated that the main consequences of these ergonomic risks included chronic back pain (Rossi *et al.*, 2022) and inflammatory conditions (muscles, tendons, nerves, joints, ligaments) (Van Nguyen *et al.*, 2020; Ziaei *et al.*, 2019).

Furthermore, studies indicated that waste collectors were exposed to multiple occupational risks due to the complex nature of their work. These included physical, chemical, biological, mechanical, and psychological risks, which contributed to the development of various occupational diseases, such as gastrointestinal tract infections and skin allergies (Hossain *et al.*, 2024; Kaphle *et al.*, 2024; Sangkham *et al.*, 2021).

**Table 2.** Risk factors affecting solid waste collection workers.

| Title/Reference                                                                                                                                               | Country    | Population sample                    | Main Work Task                                                                                       | Occupational risk                                                      | Type of disease found                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|--------------------------------------|------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| Occupational health problems among waste collectors in a metropolitan city: a cross-sectional study. (Kaphle <i>et al.</i> , 2024)                            | Nepal      | 158 household waste collectors       | Street cleaners and solid waste workers, who perform repetitive physical tasks and awkward postures. | Physical, biological, ergonomic, psychological                         | MSDs: physical injuries, gastrointestinal tract infections, skin allergies.                                   |
| Occupational health hazards and the use of safety protective measures among municipal solid waste collectors. (Elsayed Farid Amr & Abdel Malek Hussein, 2021) | Egypt      | 140 municipal solid waste collectors | Cleaning the streets, caring for and lifting solid waste. Evacuate refuse containers into trucks.    | Physical, chemical, biological, mechanical, ergonomic, psychological.  | Respiratory diseases, skin problems, stomach infections, MSDs: back pain.                                     |
| Occupational health hazard exposure and health problems among solid waste collectors in Phayao Province, Northern Thailand. (Sangkham <i>et al.</i> , 2021)   | Thailand   | 107 solid waste collectors           | Lifting and loading waste from containers and pick-up locations.                                     | Physical, chemical, biological, ergonomics, mechanicals, psychosocial. | MSDs: musculoskeletal pain, respiratory and skin diseases.                                                    |
| Musculoskeletal pain and work-related risk factors among waste collectors in Hanoi, Vietnam: a cross-sectional Study. (Van Nguyen <i>et al.</i> , 2020)       | Vietnam    | 468 waste collectors                 | Awkward postures.                                                                                    | Physical, ergonomics, Psychosocial.                                    | MSDs: inflammatory conditions affecting the supporting blood vessels, nerves, joints, ligaments, and muscles. |
| Health challenges among waste collectors in Bangladesh: exploring risk factors using multi-level modeling. (Hossain <i>et al.</i> , 2024)                     | Bangladesh | 481 waste collectors                 | Repetitive and physically demanding activities                                                       | Physical, chemical, biological, mechanicals, psychosocial.             | Gastrointestinal, dermatological diseases. MSDs: chronic pain conditions                                      |

| Title/Reference                                                                                                                                         | Country | Population sample       | Main Work Task                                                                                                                                                  | Occupational risk         | Type of disease found                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|---------|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-----------------------------------------------------------------------------------------------------------------------|
| A comparison of different waste collection methods: Environmental impacts and occupational risks. (Rossi <i>et al.</i> , 2022)                          | Italy   | Not specify sample size | Pulling bins towards the compactor, hooking the bin, activating the automatic emptying system, unhooking the bin, and pushing it back to its original location. | Ergonomics, psychosocial. | MSDs: back pain, chronic pain conditions in back, neck, shoulders, and limbs.                                         |
| Psychological and physical job demands, decision latitude, and work-related social support among Iranian waste collectors. (Ziaei <i>et al.</i> , 2019) | Iran    | 200 waste collectors    | Lifting and carrying waste containers, pulling heavy loads, and performing repetitive tasks.                                                                    | Ergonomics and physical.  | MSDs: including tendons, ligaments, cartilage, muscles, and nerves. Respiratory problems, and cardiovascular diseases |

Abbreviation: MSDs (musculoskeletal disorders)

## Discussion

Studies on occupational hazards among waste collection workers were mainly conducted in Asia countries (Hossain *et al.*, 2024; Kaphle *et al.*, 2024; Sangkham *et al.*, 2021; Van Nguyen *et al.*, 2020; Ziaei *et al.*, 2019), where mainly door-to-door collection is employed. Only one study (Rossi *et al.*, 2022) was conducted in Europe and another one in Africa (Elsayed Farid Amr & Abdel Malek Hussein, 2021). These studies demonstrate that the SWC door-to-door system is a high-risk occupation due to the various work-related diseases reported as a consequence of this activity (Elsayed Farid Amr & Abdel Malek Hussein, 2021; Kaphle *et al.*, 2024; Ziaei *et al.*, 2019). Additionally, some studies reported psychosocial risks among workers (Elsayed Farid Amr & Abdel Malek Hussein, 2021; Hossain *et al.*, 2024; Kaphle *et al.*, 2024; Rossi *et al.*, 2022; Sangkham *et al.*, 2021; Van Nguyen *et al.*, 2020; Ziaei *et al.*, 2019), which could be associated with exposure to ergonomic hazards, as all studies reported. The consequences observed in workers were not only physical but also psychological.

Implementing technologies such as IoT-based waste management in this field enables task automation, and reduces workload. The placement of smart bins in strategic locations could help decrease occupational risk exposure. In fact, one study mentions that the door-to-door collection method exposes workers to high risks, which could be mitigated with the use of smart technologies (Jasim *et al.*, 2021). The level of ergonomic risk decreases as forced postures, repetitive tasks, and heavy lifting and dragging are eliminated with smart technology implementation. Another advantage of this technology is its environmental contribution, as it enhances the automation of waste sorting tasks (Abidin *et al.*, 2022) and improves the accuracy of gas concentration monitoring in smart bins (I. Hussain *et al.*, 2024).

Nevertheless, implementing IoT-based waste management systems in countries with door-to-door collection models, where mechanical, physical, chemical, ergonomic, biological, and psychosocial hazards are prevalent, may encounter several challenges. These challenges include the need to restructure the existing collection system, which would significantly increase costs related to technological investments and the public's re-education on new collection procedures. However, studies indicate that the cost-benefit ratio of maintaining this technology is justified by the advantages it brings to waste collection systems, particularly in smart cities (I. Hussain *et al.*, 2024). These benefits include environmental sustainability, gas emission monitoring, and process automation, reducing waste collection operations' human labor.

Finally, integrating smart technologies in solid waste collection systems presents a promising approach to reducing occupational risks and improving operational efficiency. While challenges exist, particularly in developing regions, the long-term benefits in terms of worker safety, environmental sustainability, and automation outweigh the initial implementation costs. Future studies should focus on optimizing these technologies to ensure broader accessibility and effectiveness.

## Conclusions

SWC remains a high-risk occupation, particularly in countries, where door-to-door collection systems expose workers to multiple occupational risks. These include ergonomic risks due to repetitive tasks, heavy lifting, awkward postures, and psychosocial and environmental hazards stemming from prolonged exposure to contaminated waste and harmful gases. The findings of this study highlight the urgent need for innovative solutions to reduce these risks and improve working conditions for waste collection workers.

The implementation of IoT-based waste management technologies presents a promising approach to mitigating occupational hazards, especially ergonomics risk, predominant in the door-to-door SWC system. Smart bins equipped with fill-level sensors, weight measurement systems, and real-time communication capabilities help optimize collection routes, reducing physical strain and minimizing direct human contact with waste. Additionally, the automation of waste sorting and gas concentration monitoring contributes to both worker safety and environmental sustainability.

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# COMPREENDENDO O IMPACTO DO TRABALHO POR TURNOS NA QUALIDADE DO SONO DOS POLÍCIAS MUNICIPAIS

## UNDERSTANDING THE IMPACT OF SHIFT WORK ON THE SLEEP QUALITY OF MUNICIPAL POLICE OFFICERS

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### Abstract

**Background and Objective:** According to the literature, poor sleep quality in the police work has an impact on health, performance and safety of these professionals. The study sought to evaluate the sleep quality and the influence of shift work in a sample of municipal police officers. **Method:** Exploratory, cross-sectional study, carried out through an online questionnaire, in a convenience sample of (n=50) municipal police officers. Sleep quality was assessed using the PSQI index, by applying the *Pittsburgh Sleep Quality Index* questionnaire. **Results:** The mean PSQI index was  $8,6 \pm 3,9$ , and 78,6% of the respondents had poor sleep quality (PSQI > 5). The number of hours slept was on average  $5,2 \pm 1,1$  hours, below the recommended level, and a significant percentage of respondents (16,7%) took sleep medication at least once a week. The police officers who work shifts had a mean PSQI index tending to be higher than that of colleagues who have a stable daytime schedule, but the difference was not significant ( $p\text{-value} > 0,05$ ). **Conclusions:** Given the observed poor sleep quality in the sample and the possible relation with shift work, action measures are proposed, in order to promote health and safety of municipal police officers.

**Keywords:** Sleep, Chronodisruption, Shift work, *Pittsburgh Sleep Quality Index*, Municipal Police.

### Resumo

**Introdução e Objectivo:** De acordo com a literatura, a deficiente qualidade do sono entre os polícias tem impacto na saúde, performance e segurança destes profissionais. O estudo procurou avaliar a qualidade do sono e influência do trabalho por turnos, numa amostra de polícias municipais. **Metodologia:** Estudo exploratório, transversal, realizado através de questionário *online*, numa amostra de conveniência de (n=50) polícias municipais. Foi aplicado o questionário *Pittsburgh Sleep Quality Index* e determinado o índice PSQI, para avaliação da qualidade do sono. **Resultados:** A média do índice PSQI foi  $8,6 \pm 3,9$ , sendo que 78,6% dos respondentes apresentaram uma deficiente qualidade do sono (PSQI > 5). O número de horas dormidas foi em média  $5,2 \pm 1,1$  horas, abaixo do recomendado, e uma percentagem considerável dos respondentes (16,7%) tomam medicação para dormir pelo menos 1 vez por semana. Os polícias que fazem turnos apresentaram uma média de índice PSQI tendencialmente superior à dos colegas que têm um horário diurno estável, mas a diferença não é significativa ( $p\text{-value} > 0,05$ ). **Conclusões:** Dada a deficiente qualidade do sono observada e a possível relação com o trabalho por turnos, são propostas medidas de atuação, no sentido de promover a saúde e segurança dos polícias municipais.

**Palavras-chave:** Sono, Cronodisrupção, Trabalho por Turnos, *Pittsburgh Sleep Quality Index*, Polícia Municipal.

### Introdução

Os distúrbios do sono são muito comuns entre os polícias (Garbarino *et al.*, 2020; Sørengaard *et al.*, 2021), surgindo muitas vezes associados ao trabalho por turnos, uma modalidade de organização do trabalho inevitável numa profissão que tem por missão assegurar a segurança das comunidades em contínuo (Garde *et al.*, 2020;

Waggoner *et al.*, 2012). A disfunção causada pelo trabalho por turnos (*shift work disorder*) é devida à perturbação do ciclo circadiano e conduz a sonolência diurna, insónia, absentismo e mesmo perturbações ao nível social (Rajaratnam *et al.*, 2011). A deficiente qualidade do sono surge associada a consequências na saúde dos polícias, como a síndrome metabólica (McCanlies *et al.*, 2012), doença cardiovascular, depressão e *burnout* (Rajaratnam *et al.*, 2011).

A deficiente qualidade do sono é ainda associada a um risco acrescido de lesão no trabalho, de forma transversal a várias profissões, dado que deteriora o funcionamento cognitivo. A importância do sono no âmbito da Segurança e Saúde no Trabalho, levou a *American Association of Occupational Environmental Medicine* e a *Italian Society of Occupational Health* a proporem programas específicos de gestão do sono, como parte integrante do sistema de gestão do risco ocupacional (Lerman *et al.*, 2012).

Garbarino *et al.* (2020) verificaram, numa amostra de polícias, que todas as variáveis de sono estavam significativamente associadas às variáveis acidentes de trabalho e lesões, e a sonolência foi mesmo o melhor preditor dos acidentes de trabalho. Verificaram também que no modelo multivariado, a (in)satisfação com o sono e os sintomas de insónia foram os melhores preditores de incidentes ou quase-acidentes.

De facto, os polícias dependem de um bom funcionamento cognitivo, para tomar decisões racionais num curto intervalo de tempo, nomeadamente na resposta ao crime e violência. Uma redução cognitiva devida a um sono deficiente, pode constituir um perigo grave nesta profissão, quer para o polícia, quer para os cidadãos com que o polícia interage (Sørengaard *et al.*, 2021), dado que polícias cansados se tornam irritáveis e impulsivos, o que constitui um problema dadas as suas obrigações e poderes (Vila, 2006).

A sonolência é ainda considerada uma importante causa dos acidentes de viação entre polícias (Garbarino *et al.*, 2001), sendo que num estudo de polícias dos EUA e Canadá, 26,1% dos respondentes reportaram ter adormecido pelo menos uma vez por mês enquanto conduziam (Rajaratnam *et al.*, 2011).

Pelo exposto, o *National Institute for Occupational Safety and Health (NIOSH)* e o *Centers for Disease Control (CDC)* desenvolveram projetos, desde 2003, no sentido da prevenção e mitigação do impacto de um sono inadequado na saúde, segurança e performance dos polícias (Vila, 2006).

Face à escassez de estudos sobre a temática em Portugal, o presente estudo procurou avaliar a qualidade do sono e a relação desta com o trabalho por turnos, numa amostra de polícias municipais, visando contribuir para o conhecimento da realidade deste grupo profissional e propor medidas de atuação informadas. As Polícias Municipais cooperaram com a Polícia de Segurança Pública na proteção das comunidades locais, exercendo funções de vigilância (ex. de espaços públicos e transportes urbanos), conforme as competências e poderes de autoridade definidos na Lei nº 140/99, de 28 de agosto. No exercício das suas funções, os polícias municipais podem deparar-se com crimes e atos violentos, sendo-lhes permitido o uso de meios coercivos.

## **Materiais e métodos**

### ***Instrumento de investigação***

No presente estudo, foi aplicado o *Pittsburgh Sleep Quality Index (PSQI)* (Buysse *et al.*, 1989), um questionário validado e amplamente utilizado para avaliar a qualidade do sono. Composto por 19 itens de autoavaliação e 5 itens adicionais para resposta de um companheiro de quarto (não considerados no cálculo do índice), refere-se à experiência dos últimos 30 dias. As respostas variam de 0 a 3, onde pontuações mais altas indicam pior qualidade do sono. Os 19 itens estão agrupados em 7 componentes: (1) qualidade subjetiva do sono, (2) latência do sono, (3) duração do sono, (4) eficiência habitual do sono (percentagem de sono efetivo em relação ao tempo na cama), (5) distúrbios do sono, (6) uso de medicação para dormir e (7) disfunção diurna (sonolência e dificuldade em manter-se acordado durante o dia). Cada componente é pontuada conforme Buysse *et al.* (1989), e o índice PSQI (0–21 pontos) resulta da soma dessas pontuações. De acordo com o critério dos mesmos autores, o indivíduo tem uma deficiente qualidade de sono se o valor do índice PSQI for superior a 5.

O questionário incluiu uma secção de caracterização sociodemográfica e socioprofissional, mas por lapso, não foi registada a idade dos respondentes. Contudo, a antiguidade na profissão (anos de serviço como polícia municipal) pode servir como uma aproximação a essa variável.

## Procedimento

A amostra foi constituída por 50 polícias municipais, seleccionados por conveniência através de amostragem não probabilística. Foi solicitada a colaboração das chefias, após o que a divulgação do questionário foi efetuada através de correio eletrónico enviado aos polícias municipais, acompanhado de um vídeo explicativo. O questionário foi disponibilizado através da plataforma *Microsoft Forms* (<https://forms.office.com>), entre 31 de julho e 5 de setembro de 2023. Foi precedido por um Consentimento Informado, sendo de participação anónima e voluntária, em conformidade com a Declaração de Helsínquia.

## Métodos estatísticos

Os resultados foram analisados no software IBM SPSS Statistics 29. Calcularam-se medidas de tendência central e de dispersão, correlações de Pearson e Spearman (para associações paramétricas e não paramétricas, respetivamente) e aplicaram-se os testes não paramétricos de Mann-Whitney e de Kruskal-Wallis, para verificar diferenças significativas entre dois ou mais grupos independentes. Foi adotado o nível de significância de 0,05. A consistência interna do *Pittsburgh Sleep Quality Index (PSQI)* foi avaliada pelo Alpha de Cronbach, com um valor global de 0,846, indicando consistência alta (Landis & Kock, 1977).

## Resultados

### Caracterização da amostra

A amostra foi composta por 50 polícias municipais (num universo de cerca de 900 agentes em atividade, de acordo com informação do Sindicato Nacional das Polícias Municipais), dos quais apenas 5 (10%) são do sexo feminino. Quanto ao estado civil, 90% são casados ou em união de facto. Em termos de escolaridade, 82% concluíram o ensino secundário, 14% têm formação superior e 4% possuem apenas o ensino básico. A maioria (76%) trabalha por *turnos diurnos e noturnos rotativos*, enquanto 20% não realizam turnos e 4% têm turnos exclusivamente diurnos ou noturnos. Todos os respondentes têm mais de 11 anos de serviço, sendo que 80% possui mais de 20 anos de experiência policial. A maioria dos participantes enquadra-se nas categorias profissionais de *Agente Coordenador, Agente Principal ou Agente* (82%) e *Chefe-Coordenador, Chefe-principal ou Chefe* (12%), contando-se ainda 1 Sub-intendente e 1 Comissário.

Na análise da qualidade do sono, foram excluídos 8 respondentes por não indicarem o horário habitual de deitar, impedindo o cálculo da eficiência do sono e consequentemente, do índice PSQI. Considerou-se também excluir 7 participantes que relataram o uso de medicação para dormir *3 ou mais vezes por semana*, devido ao possível enviesamento dos resultados. No entanto, como todos apresentaram um índice PSQI superior a 5, indicando má qualidade do sono, optou-se por manter os participantes na análise.

### Caracterização da qualidade do sono nos polícias municipais da amostra

Apresentam-se seguidamente os resultados dos itens do questionário *Pittsburgh Sleep Quality Index* que permitem o cálculo de cada uma das 7 componentes do índice PSQI, conforme a metodologia de Buysse *et al.* (1989). A *qualidade subjetiva do sono* (componente 1), é classificada como *Má* ou *Muito má* por 57,1% dos respondentes, sendo que apenas 1 respondente a classificou como *Muito boa*. Em relação à *latência do sono* (componente 2), e no tocante à frequência com que os respondentes tiveram dificuldade em adormecer em 30 minutos, observa-se que a ocorrência mais comum foi de *três ou mais vezes por semana* (35,7%) e 50% tiveram dificuldade em adormecer pelo menos uma vez por semana. Quando questionados sobre a *duração do sono* (componente 3), o número de horas dormidas reportado foi em média de  $5,2 \pm 1,1$  horas.

A *eficiência do sono* (componente 4), calculada através da proporção entre o número de horas dormidas e o tempo total passado na cama, revelou-se bastante satisfatória, com 24 respondentes a apresentar uma eficiência do sono superior a 85%. No entanto, é de referir que 7 respondentes apresentam uma eficiência do sono inferior a 65%. A componente *distúrbios do sono* (componente 5) identifica as razões que tornaram difícil dormir no último mês, verificando-se que as situações mais recorrentes se prendem com a *dificuldade em adormecer* ou *ter acordado a meio da noite ou de manhã cedo*. No tocante ao *uso de medicação para dormir* (componente 6),



verifica-se que a maioria não recorreu a este tipo de medicação no último mês, existindo contudo, 23,8% que o fizeram, e em particular, 16,7% que o fizeram *três ou mais vezes por semana*. Relativamente à *disfunção diurna* (componente 7), e em concreto à *dificuldade em manter-se acordado enquanto conduzia, comia ou participava numa atividade social*, 54,8% dos respondentes afirmou que tal havia acontecido no último mês; e quando questionados sobre *quão problemático foi manter o entusiasmo (ânimo) para fazer as atividades habituais*, 66,7% assumiram dificuldades, sendo que 28,6% o definiram como “um problema razoável” ou “um grande problema”.

Entre os 42 respondentes avaliados, 33 (78,6%) apresentaram um índice PSQI > 5 (Figura 1), indicando uma deficiente qualidade do sono (Buysse *et al.*, 1989). A média de índice PSQI foi  $8,6 \pm 3,9$ .

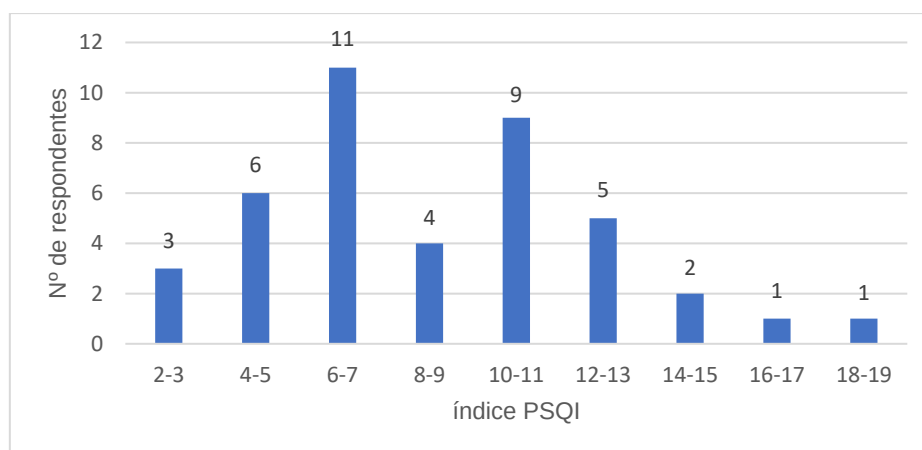


Figura 1. Histograma do índice PSQI na amostra.

### ***Influência do trabalho por turnos e variáveis sociodemográficas/socioprofissionais no índice PSQI***

Não se verifica diferença significativa de índice PSQI entre classes de sexo, número de filhos, categoria profissional ou antiguidade na profissão ( $p\text{-value} > 0,05$ ).

A Figura 2 apresenta a média do índice PSQI por classe de trabalho por turnos. Embora se observe uma tendência para um valor de índice PSQI mais elevado entre os respondentes que fazem turnos noturnos, verifica-se não existir diferença significativa de índice PSQI entre classes de turnos ( $p\text{-value} > 0,05$ ).

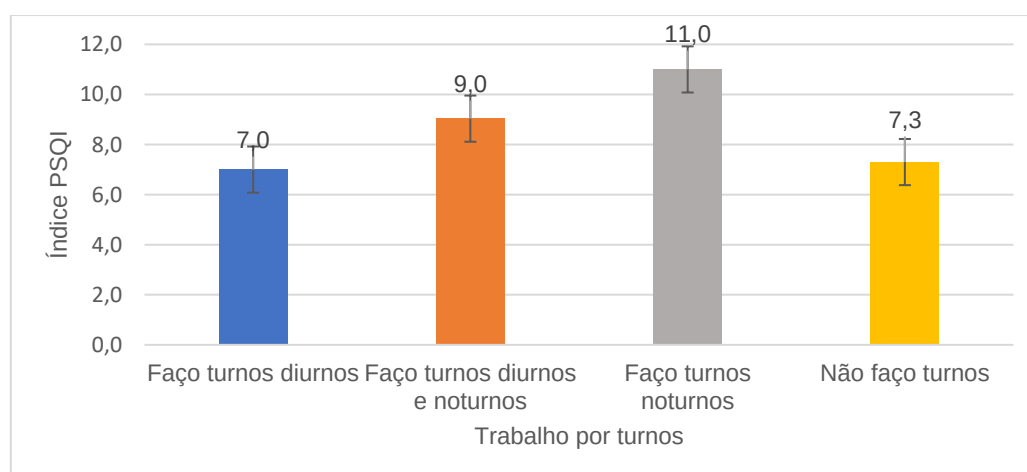


Figura 2. Média (e incerteza padrão) de índice PSQI por classe de trabalho por turnos.

### **Discussão**

#### ***Como se caracteriza a qualidade de sono dos polícias municipais da amostra?***

Como referido, a média do índice PSQI na amostra foi  $8,6 \pm 3,9$ , e 78,6% dos 42 respondentes apresentaram qualidade do sono deficiente (PSQI > 5) (Buysse *et al.*, 1989), o que indica resultados preocupantes.



Garbarino *et al.* (2019) realizaram uma revisão da literatura sobre a qualidade do sono entre polícias, selecionando estudos que aplicaram o PSQI. Dos 1149 estudos iniciais, incluíram 13 artigos na meta-análise, num total de 3722 polícias. A média agregada de índice PSQI nos vários estudos foi 5,6 (IC 95% 5,0–6,3), indicando uma baixa qualidade do sono. A prevalência de deficiente qualidade do sono variou entre 23% e 79%, com média agregada de 51,1% (IC 95% 41,8-60,3%). Elliott & Lal (2016) reportaram uma média de índice PSQI de  $6,83 \pm 3,58$ , numa amostra de polícias australianos, e Ma *et al.* (2019) reportaram uma média de  $6,5 \pm 3,4$ , numa amostra de polícias de Nova York.

Conclui-se que a média de índice PSQI e a percentagem de respondentes com deficiente qualidade do sono do presente estudo são elevadas. A prevalência de deficiente qualidade do sono é superior, por exemplo, aos valores encontrados por Fekedulegn *et al.* (2016) (53,9%) e Neylan *et al.* (2002) (64%), em amostras de polícias americanos.

Na amostra analisada, a disfunção diurna afetou mais de metade dos respondentes (54,8%), uma percentagem elevada face à prevalência de sonolência excessiva observada por Rajaratnam *et al.* (2011) (28,5%) e Yadav *et al.* (2016) (10,6%).

As recomendações da *National Sleep Foundation* (Hirshkowitz *et al.*, 2015), apontam para uma duração adequada do sono de 7 a 9 horas, para jovens adultos e adultos saudáveis. É realçado que uma duração de sono habitual inferior a este intervalo pode representar sintoma de problemas de saúde ou, se praticado de forma voluntária pelo indivíduo, pode levar ao comprometimento da sua saúde e bem-estar. Na amostra analisada, a média de horas dormidas ( $5,2 \pm 1,1$  horas) encontra-se abaixo do recomendado pela NSF. De forma semelhante, Vila *et al.* (2000) reportaram que apenas 17% dos polícias dormiam 8 horas e 53% dormiam 6,5 horas ou menos.

### ***O trabalho por turnos tem impacto na qualidade do sono dos polícias municipais da amostra?***

Os polícias municipais da amostra com turnos noturnos (fixos ou rotativos) apresentam uma média de índice PSQI tendencialmente superior à dos colegas que têm um horário diurno estável, embora esta diferença não seja estatisticamente significativa (para  $\alpha = 0,05$ ).

Também a meta-análise de Garbarino *et al.* (2019), revelou uma associação marginalmente significativa ( $p\text{-value} \approx 0,05$ ) entre o índice PSQI e o trabalho por turnos. Alguns estudos, contudo, foram inconclusivos ou não encontraram diferenças significativas entre classes de turnos, concluindo que independentemente do horário, os polícias manifestam uma deficiente qualidade de sono (Neylan *et al.*, 2002; Ramey *et al.*, 2012). Estes resultados destacam a necessidade de serem estudadas outras variáveis potencialmente influenciadoras da qualidade do sono, como o stress.

O trabalho por turnos está frequentemente associado a uma pior qualidade do sono entre os polícias, refletindo-se em problemas como a redução da duração do sono (Garde *et al.*, 2020; Waggoner *et al.*, 2012). Ramey *et al.* (2012) observaram uma prevalência de sono inferior a 6 horas, 14 vezes superior entre polícias de turnos não diurnos. Fekedulegn *et al.* (2016) registaram uma prevalência de deficiente qualidade do sono 72% mais elevada entre polícias do turno noturno, em comparação com os do turno diurno.

### ***A qualidade do sono é influenciada por variáveis sociodemográficas ou socioprofissionais na amostra?***

Os problemas de qualidade de sono são transversais à amostra, sem diferenças significativa no índice PSQI entre classes de variáveis sociodemográficas ou socioprofissionais. A média de índice PSQI foi idêntica entre homens e mulheres (8,6), sendo no entanto de realçar o número reduzido de respondentes do sexo feminino (5 em 42, 11,9%). Estes resultados alinham-se com Neylan *et al.* (2002), que também não encontraram diferença significativa entre sexos. No entanto, Vila *et al.* (2000) reportaram um índice PSQI significativamente mais elevado em mulheres (5,8) do que em homens (5,2), num estudo em que a representatividade feminina também foi limitada (10,4%).

Na amostra, não se observam diferenças significativas de índice PSQI em função da antiguidade na profissão ou da categoria profissional. A literatura apresenta resultados contraditórios sobre o impacto da antiguidade na qualidade do sono. Vila *et al.* (2000) associaram maior antiguidade a pior qualidade do sono, sugerindo o

desenvolvimento de distúrbios do sono ao longo do tempo, ou menor resiliência à cronodisrupção com a idade. Em contraste, a meta-análise de Garbarino *et al.* (2019), identificou uma associação negativa significativa, indicando que maior senioridade pode estar ligada a melhor qualidade do sono, possivelmente devido a mecanismos adaptativos.

### Limitações

Este é um estudo exploratório, baseado numa amostra de conveniência, de dimensão reduzida, e com um desenho transversal, o que limita a generalização dos resultados e impede a inferência de relações causais. Recomenda-se a replicação do estudo com uma amostra de maior dimensão e maior representatividade de respondentes do sexo feminino.

Os dados foram obtidos por questionário de auto-relato, suscetível a viés de memória e viés de resposta, dado o potencial para respostas socialmente desejáveis, especialmente numa profissão marcada por um estereótipo masculino, onde os participantes podem hesitar em expor “fragilidades”. Contudo, o caráter anónimo e voluntário do inquérito pode atenuar este efeito.

Por fim, a discussão dos resultados suporta-se na literatura existente sobre a profissão de polícia em geral, e não especificamente sobre a polícia municipal, devido à ausência de estudos dedicados a esta última. Apesar das semelhanças, existem diferenças funcionais que devem ser consideradas.

### Conclusões e propostas de atuação

No presente estudo, avaliou-se a qualidade do sono e a possível influência do trabalho por turnos, numa amostra não probabilística de 50 polícias municipais, através de um desenho transversal. Os resultados obtidos, nomeadamente a média do índice PSQI, a percentagem de respondentes com deficiente qualidade do sono (PSQI > 5) e o número médio de horas dormidas, refletem uma realidade preocupante.

Observou-se que os polícias que trabalham em turnos noturnos, ou em regime rotativo diurno-noturno, apresentam uma média de índice PSQI tendencialmente superior à dos colegas com horário diurno estável. Este resultado confirma, em certa medida, o impacto do trabalho por turnos na cronodisrupção dos polícias da amostra, mas também sugere a influência de outros fatores (como ex. o stress).

É fundamental implementar medidas de prevenção e mitigação da deficiente qualidade do sono. Foram já testados vários programas de promoção da saúde dos polícias com enfoque na qualidade do sono, nomeadamente os programas propostos por James *et al.* (2018) e Kuehl *et al.* (2016). Sendo a sonolência uma importante causa dos acidentes ocupacionais e dos acidentes de viação, devem ser aplicadas aos polícias, abordagens de gestão do risco de fadiga como as implementadas na aviação e transportes. Entre as medidas recomendadas, destacam-se o treino em higiene do sono, que deverá reforçar a necessidade de dormir pelo menos 7 horas por noite e reduzir os elementos que interferem com um sono normal (ex. consumo de cafeína e a utilização de equipamentos eletrónicos), bem como promover comportamentos potenciadores de um bom sono (ex. deitar e acordar à mesma hora). Os polícias devem ser levados a pensar quais os fatores que contribuem para a sua deficiente qualidade do sono, e propor medidas que possam ajudar a resolver o problema, no seu caso concreto. A literatura também destaca a importância de programas de exercício físico para combater problemas do sono (e o stress), pelo que um programa de saúde e bem-estar para os polícias deve incluir a atividade física no horário de trabalho. Adicionalmente, o Médico do Trabalho deverá desempenhar um papel fundamental no diagnóstico e tratamento das perturbações do sono, como indicado no documento *Guidelines for the Health Surveillance of Police Forces: a gap to be filled*, da Italian Society of Occupational Health SIML.

Não sendo possível eliminar o trabalho por turnos nesta profissão, e existindo evidência de que a duração, rotatividade e intervalo entre turnos têm influência na qualidade do sono, fadiga, sonolência e performance dos polícias, urge aplicar estratégias de reorganização de turnos assentes nos estudos existentes, no sentido de proporcionar o tempo para o descanso e a conciliação entre a vida profissional, pessoal e familiar. Embora a literatura não seja consensual no tocante à duração e rotatividade dos turnos, é recomendado na literatura mais recente, por exemplo, que o horário tenha três ou menos turnos noturnos consecutivos (“rotação rápida”), que a

rotação seja feita no sentido dos ponteiros do relógio (com mudança de turno diurno para turno noturno, e não o contrário) para reduzir a disrupção do ciclo circadiano, que o intervalo entre turnos seja de pelo menos 11 horas, e que o turno tenha 9 ou menos horas de duração (Garde *et al.*, 2020). São também recomendadas sestas curtas antes do turno noturno (Garbarino *et al.*, 2020). É aconselhável que os polícias tenham uma voz ativa na escolha e calendarização dos turnos em que trabalham, para levar em consideração o grau de suporte familiar de que o polícia dispõe, e também no sentido de ser feito o alinhamento possível com o cronotipo do indivíduo. De realçar que os beneficiários destas intervenções de promoção da saúde ocupacional não são apenas os próprios polícias, mas também as suas famílias, as organizações policiais e a sociedade em geral.

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# SISTEMA DE GESTÃO DE SEGURANÇA E SAÚDE DO TRABALHO NUMA INDÚSTRIA DE CALÇADO: PROPOSTA E IMPLEMENTAÇÃO DE MODELO DE INTEGRAÇÃO

## OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT SYSTEM IN A FOOTWEAR INDUSTRY: PROPOSAL AND IMPLEMENTATION OF AN INTEGRATION MODEL

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### Abstract

**Introduction:** Due to the increased awareness of companies regarding occupational health and safety and their business performance, they are increasingly looking to implement integrated management systems in quality, environment and safety to assert themselves in their markets and to have greater control of all their activities, based on a risk management approach that enables business sustainability. **Objective:** This project proposes designing and implementing an Occupational Health and Safety Management System based on the NP ISO 45001:2019 standard, integrated into the existing Management Systems of a footwear manufacturing company. **Materials and methods:** An initial check was carried out to assess the compliance of the QMS with the respective standard, followed by the drawing up of a planning, design and implementation schedule for the OSHMS. **Results and discussion:** Based on the results obtained, it was found that after reviewing and drawing up the documentation base for the OSHMS, the company showed a significant increase in compliance with the respective requirements of the NP ISO 45001:2019 standard. **Conclusions:** The proposed Integrated Quality, Environment and Safety Management System has enabled the company under study to deepen its knowledge of NP ISO 45001:2019 and to develop a proactive occupational safety culture.

**Keywords:** Integrated Management System; Occupational Safety; ISO 45001; Risk Management; Footwear Industry.

### Resumo

**Introdução:** Devido à maior consciencialização das empresas relativamente à saúde e segurança no trabalho e ao seu desempenho empresarial, estas procuram cada vez mais implementar sistemas de gestão integrados na qualidade, ambiente e segurança, de forma a afirmarem-se nos seus mercados e a terem um maior controlo de todas as suas atividades, assente numa abordagem de gestão de risco que permita a sustentabilidade do negócio. **Objetivo:** Este projeto propõe a conceção e implementação de um Sistema de Gestão da Segurança e Saúde no Trabalho baseado na norma NP ISO 45001:2019, integrado nos Sistemas de Gestão existentes, de uma empresa de fabrico de calçado. **Materiais e métodos:** Foi realizada uma verificação inicial para avaliar a conformidade do SGQ com a respetiva norma, seguindo-se a elaboração de um cronograma de planeamento, conceção e implementação do SGSST. **Resultados e discussão:** Com base nos resultados obtidos, verificou-se que após a revisão e elaboração da base documental do SGSST, a empresa apresentou um aumento significativo da conformidade com os respetivos requisitos da norma NP ISO 45001:2019. **Conclusões:** O Sistema Integrado de Gestão da Qualidade, Ambiente e Segurança proposto permitiu à empresa em estudo aprofundar o conhecimento da NP ISO 45001:2019 e desenvolver uma cultura proactiva de segurança no trabalho.

**Palavras-chave:** Sistema de Gestão Integrado; Segurança do Trabalho; ISO 45001; Gestão dos Riscos; Indústria de Calçado.

### Introdução

Numa realidade onde o mercado se encontra cada vez mais globalizado, competitivo e com clientes cada vez mais exigentes e rigorosos, as organizações procuram por mudanças e soluções para melhorar os seus produtos e/ou serviços. Com isso surge a necessidade por parte das organizações de revigorar e encontrar novas formas de gestão que permitam responder aos desafios que aparecem constantemente. E, como tal, é cada vez maior o



número de organizações que procuram implementar um Sistema de Gestão Integrado (SGI) (Cardoso, 2018; Chongo, 2021).

Desta forma, as tendências sociais, políticas e económicas atuais, assim como a crescente dependência da tecnologia, as alterações climáticas e a globalização dos vários mercados, influenciam cada vez mais o quotidiano dos trabalhadores. Estas forças estruturais, por sua vez, moldam os padrões de emprego e trabalho, com implicações para a disponibilidade e qualidade dos empregos, assim como na natureza das relações entre empregadores e trabalhadores (Sorensen *et al.*, 2021).

Compreender estas dinâmicas torna-se, desta forma, fundamental para prever as consequências de futuras mudanças nas condições de trabalho e, em última análise, servirá como base para a tomada de decisões em torno de políticas e práticas destinadas a proteger e promover a segurança, a saúde e o bem-estar dos trabalhadores. Assim, a segurança e saúde no trabalho (SST) traz não apenas vantagens a curto-médio prazo, mas também a longo prazo, promovendo assim a capacidade de trabalho, a produtividade, qualidade, a motivação dos trabalhadores e a segurança no emprego. A prevenção é, assim, um pré-requisito para que os trabalhadores tenham uma vida digna e para as empresas alcançarem sucesso entre os seus competidores no mercado nacional e global (Freitas, 2016).

Deste modo, uma boa cultura de segurança ocupacional em todos os níveis da organização torna-se essencial para auxiliar a criação de bons ambientes de trabalho que garantem as condições de segurança necessárias e asseguram um desempenho satisfatório em SST.

A criação de uma cultura de SST é auxiliada pela existência de legislação em matéria de segurança e saúde do trabalho. Para além do cumprimento com as suas obrigações legais, a legislação serve também como guia para garantir que as empresas possam proteger os seus trabalhadores face aos riscos a que estes se encontram expostos aquando o desempenho profissional no contexto das organizações.

Porém, os recursos económicos, humanos e materiais podem dificultar o cumprimento dos requisitos legais a que as empresas têm de responder, especialmente nas pequenas e médias empresas. Consequentemente, o conhecimento e a compreensão da legislação tornam-se um desafio para as mesmas, dependendo do seu contexto (Salguero-Caparrós *et al.*, 2020).

Face ao exposto, e devido à crescente exposição mediática que os acidentes de trabalho têm vindo a adquirir, e à consequente pressão exercida pela própria sociedade e sinistrados, algumas empresas já começaram a ter outra abordagem em relação a segurança e saúde no trabalho e de uma forma mais sistemática e integrada, com outros normativos, nomeadamente os Sistemas de Gestão da Qualidade (ISO 9001) e Ambiental (ISO 14001).

Um sistema de gestão consiste em diversos elementos interrelacionados ou que trabalhem em conjunto, de uma determinada organização para o estabelecimento de políticas, objetivos e de processos para atingir esses objetivos (IPQ, 2019).

No contexto da Segurança e Saúde do Trabalho, o objetivo de um sistema de gestão é proporcionar uma estrutura para gerir os riscos e as oportunidades para a SST e, assim, prevenir lesões e afeções da saúde relacionadas com o trabalho e proporcionar locais de trabalho seguros e saudáveis (IPQ, 2019).

Um SGSST pode potenciar mais melhorias significativas na segurança no local de trabalho, e é um indicador confiável de desempenho médio de segurança, provendo uma visão importante para as partes interessadas externas, entre elas clientes e fornecedores (Viswanathan *et al.*, 2024).

A NP ISO 45001:2019 é a norma que especifica os requisitos para um Sistema de Gestão em Segurança e Saúde do Trabalho (SGSST), com enfoque na gestão dos riscos e na abordagem por processos, assim como nas linhas de orientação para a sua implementação (Santos, 2018).

A implementação de um Sistema de Gestão em Segurança e Saúde no Trabalho (SST) nas pequenas e médias empresas (PME's), permite reduzir e prevenir os riscos nos locais de trabalho, e contribuir para a melhoria da qualidade de vida dos trabalhadores, permitindo ainda que as empresas, o estado, os trabalhadores e as famílias possam reduzir custos e evitar futuras perdas (Chongo, 2021; Morgado *et al.*, 2019).

A procura de clientes por empresas que possuam um SGI em qualidade, ambiente e segurança e saúde no trabalho tem-se tornado mais recorrente. Essa integração pode fazer a diferença no momento da escolha de



parcerias e negociações, permitindo que as empresas atraiam novos fornecedores e clientes que pretendem tais certificações como um indicativo de confiabilidade. Além disso, a implementação de um sistema integrado prepara as empresas para enfrentar desafios futuros e se candidatar a projetos de financiamento, nos quais a obtenção dessas certificações pode ser um requisito obrigatório. Portanto, ter um sistema integrado de gestão que abranja qualidade, ambiente e segurança e saúde no trabalho é uma estratégia crucial para as organizações destacarem-se no mercado e demonstrarem compromisso com as suas partes interessadas (Ventura *et al.*, 2018). Contudo, existem vários obstáculos para a conceção e implementação de um SGI, que podem variar dependendo do contexto de cada organização. Segundo Darzi (2024) os obstáculos podem resumir-se em; falta/insuficiência de recursos e ativos; a ausência da motivação e sensibilização por parte dos colaboradores; as diferenças de abordagem dos respetivos sistemas de gestão e os respetivos requisitos; os custos elevados de certificação e as necessidades de investimentos inicial. Existem também outras barreiras associadas ao funcionamento interno de uma organização, tais como a falta de trabalho em equipa e problemas na comunicação interna.

Face ao exposto, a relevância do tema e oportunidade dada pela organização de estudo pretende-se com este trabalho de projeto elaborar e implementar um modelo de sistema de gestão da segurança e saúde do trabalho baseado nos requisitos da NP ISO 45001:2019 numa empresa de fabrico de calçado, integrando-o com os Sistemas de Gestão da Qualidade e Ambiente já implementados e certificados na organização.

### **Materiais e métodos**

A empresa alvo de estudo tem como atividade profissional a fabricação de calçado, sediada em Felgueiras e possui mais de 80 colaboradores. A mesma começou com a fabricação de calçado clássico, porém, atualmente, foca-se também na produção de *sneakers*. A organização é certificada em Qualidade (ISO 9001) e Ambiente (ISO 14001), tendo adquirido estas em simultâneo.

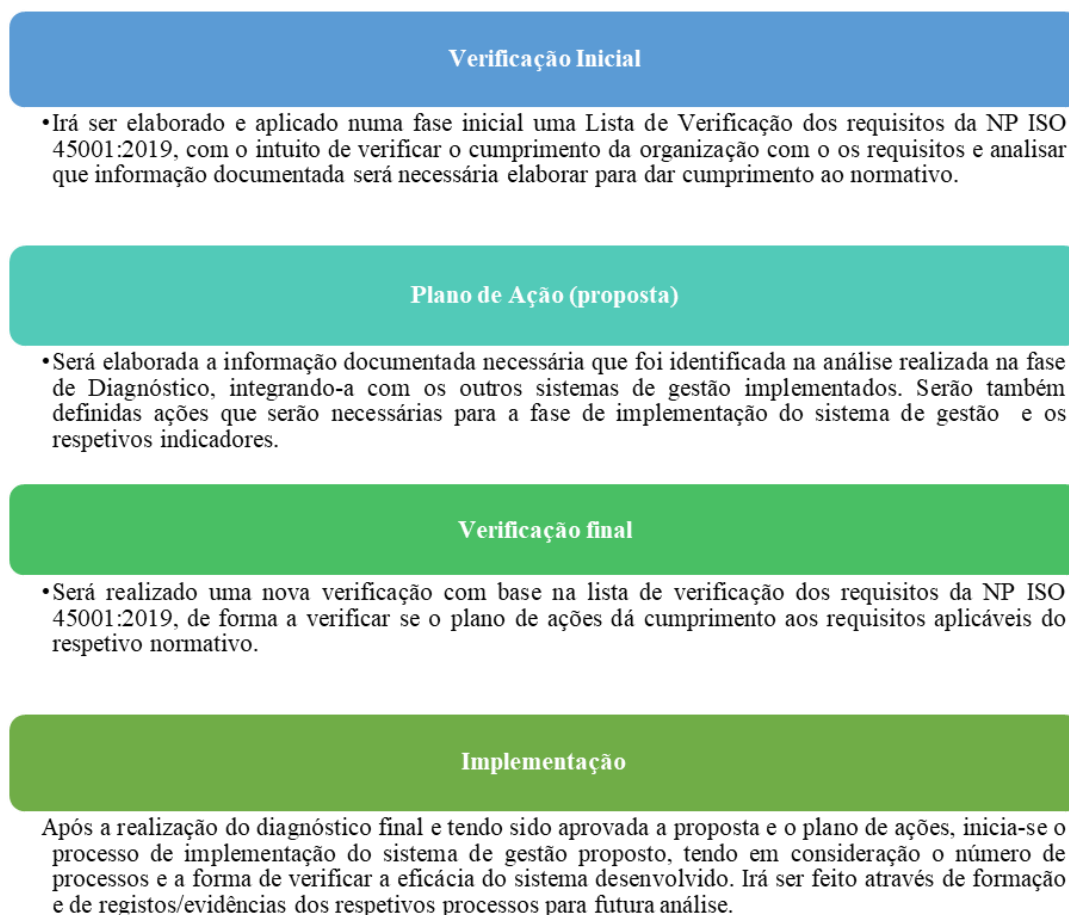
Como objetivo principal do presente trabalho de projeto pretende-se desenvolver e implementar um SGSST integrado nos sistemas de gestão existentes de Qualidade e de Ambiente na organização de estudo. Também como objetivos secundários pretende-se fazer um diagnóstico das condições de segurança e saúde do trabalho da organização e verificar de acordo com a norma NP ISO 45001:2019 a conformidade do sistema de gestão existente. Após a elaboração da informação documentada do SGSST pretende-se realizar atividades de implementação e verificar a conformidade dos requisitos aplicáveis ao sistema de gestão.

Por se tratar de um trabalho de projeto que envolve um caso prático e que exige o envolvimento de múltiplas partes, a metodologia que será utilizada é do tipo de investigação-ação.

A metodologia utilizada, por empregar abordagens participativas e colaborativas, permite desenvolver conhecimento prático através também da identificação de problemas, planeamento de ações, tomada de medidas e avaliação de ações. (Saunders *et al.*, 2012; Situmorang *et al.*, 2023)

Numa fase inicial do trabalho de projeto foi realizada uma pesquisa bibliográfica para recolha de informação referente ao tema de estudo. Para o efeito foram utilizadas várias bases de dados técnico-científicas existentes, com revisão por pares e indexação à *Web of Science* e *Science Direct* e dos repositórios de instituições de ensino superior com o intuito de se obter uma base teórica justificativa da revisão e estado da literatura da temática de estudo e compará-la com os resultados futuros. As palavras-chave utilizadas nesta etapa foram: Sistema de Gestão Integrado; Segurança do Trabalho; ISO 45001; Gestão dos Riscos; Acidentes de Trabalho; Indústria de Calçado. Foi também utilizado o operador booleano *And* para conjugação entre palavras-chave ao nível da pesquisa.

Na figura 1 estão apresentadas as várias etapas que foram adotadas durante o trabalho de projeto, bem como o descritivo das tarefas/atividades destas:



*Figura 1. Principais Etapas de Desenvolvimento do Projeto. (Fonte: Autor, 2024)*

Com o cumprimento das referidas etapas, espera-se no final que o sistema de gestão de segurança e saúde no trabalho esteja integrado com os outros sistemas de gestão já implementados na organização de estudo, de forma a atingir os objetivos previamente estabelecidos.

## **Resultados e discussão**

### **Caracterização das Condições de SST**

Inicialmente foi realizada uma vistoria das instalações da organização de estudo e, simultaneamente, aos postos de trabalho existentes na empresa, com o intuito de caracterizar as condições de SST iniciais da mesma, antes das atividades de implementação do Sistema de Gestão Integrado da Qualidade, Ambiente e Segurança, e verificar a sua conformidade com os requisitos legais em matéria de segurança e saúde do trabalho aplicáveis. Os resultados da vistoria indicam que, de forma geral, a empresa demonstra um cumprimento com os requisitos legais aplicáveis à segurança e saúde no trabalho nas instalações industriais e ao nível da sinalização e meios de proteção contra incêndio.

### **Verificação inicial**

Após uma análise documental e operacional do Sistema de Gestão Integrado da Qualidade e Ambiente já certificado na empresa, constatou-se que a empresa cumpre parcialmente com 79 % dos requisitos da NP EN ISO 45001:2019, conforme se pode verificar na tabela 1.

**Tabela 1.** Lista de Verificação Inicial da NP ISO 45001:2019. (Fonte: Autor, 2024)

| Nível | Total | 4. Contexto da organização | 5. Liderança e participação dos trabalhadores | 6. Planeamento | 7. Suporte | 8. Operacionalização | 9. Avaliação do desempenho | 10. Melhoria |
|-------|-------|----------------------------|-----------------------------------------------|----------------|------------|----------------------|----------------------------|--------------|
| C     | 8%    | 1                          | 0                                             | 0              | 1          | 0                    | 1                          | 0            |
| CP    | 79%   | 2                          | 4                                             | 6              | 4          | 7                    | 4                          | 3            |
| NC    | 13%   | 1                          | 0                                             | 2              | 2          | 0                    | 0                          | 0            |

**Legenda:** C – Conforme      CP - Conforme parcial      NC - Não conforme

Verificou-se também a existência de 3 requisitos em plena conformidade com 8%, relacionados com a "Determinação do Âmbito do Sistema de Gestão" (4.3), o "Controlo da Informação" (7.5.3) e o "Processo da Auditoria Interna" (9.2.2). Esta conformidade prévia decorre da existência de procedimentos e registos já implementados para estes requisitos, em comum com as outras normas, sendo necessário apenas uma atualização dos mesmos, após a elaboração da proposta do SGSST. Contudo, a análise também revelou 5 Não Conformidades (NC), relacionadas com requisitos específicos da NP EN ISO 45001:2019 que não são partilhados com as outras normas. Estas NC traduzem-se sobre o "Sistema de Gestão" (4.4), a "Determinação dos Requisitos Legais Aplicáveis e Outros Requisitos" (6.1.3), os "Objetivos de SST" (6.2.1), os "Recursos" (7.1) e a "Informação Documentada" (7.5.1), evidenciando a necessidade de desenvolver e implementar novos procedimentos e práticas específicas para estes requisitos.

Estes resultados evidenciam que a organização já possui integrado diversos princípios e práticas de gestão de sistemas, devido à experiência prévia com a implementação das normas ISO 9001 e ISO 14001, bem como de outros códigos de conduta de responsabilidade social já implementados. Esta base sólida facilitou a integração do Sistema de Gestão de Segurança e Saúde no Trabalho no sistema de gestão existente.

### Base documental do SGSST

De seguida e com base no plano de ações, procedeu-se à etapa de desenvolvimento da documentação que se encontrava em falta ou incompleta, de modo a cumprir com os requisitos do normativo. Esta fase do projeto exigiu uma revisão abrangente da documentação do Sistema de Gestão da Qualidade e Ambiente. Na tabela 2 está apresentada a estrutura do SGI integrado com o SGSST proposto.

**Tabela 2. Estrutura documental do SGI. (Fonte: Autor, 2024)**

|                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1º<br/>NÍVEL</b> | <p><b>Manual de gestão</b><br/>Documento que descreve o sistema de gestão integrado da qualidade, ambiente e segurança (sgiqas) da empresa.</p> <p><b>Manual de funções</b><br/>Documento que define as responsabilidades, a autoridade e a relação mútua de todos os intervenientes na implementação dos requisitos do sgi.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>2º<br/>NÍVEL</b> | <p><b>Processos</b><br/>Documentos que detalham, para as várias funções e atividades da organização, os princípios aprovados no Manual de Gestão Integrado da Qualidade, Ambiente e Segurança, indicando as responsabilidades e metodologias relativos a essas funções ou atividades:<br/>         Processo de Qualidade, Ambiente e Segurança (Responsável: Responsável de Qualidade, Ambiente e Segurança);<br/>         Processo de Gestão Estratégica (Responsável: Responsável de Qualidade, Ambiente e Segurança);<br/>         Processo Comercial (Responsável: Responsável Comercial);<br/>         Processo Planeamento e controlo de produção (Responsável: Responsável de Planeamento e Produção);<br/>         Processo de amostras (Responsável: Responsável de Amostras);<br/>         Processo Expedição (Responsável: Responsável de Expedição);<br/>         Processo Compras e aprovisionamentos (Responsável: Responsável de Compras e Armazém de matérias-primas);<br/>         Processo de Gestão Recursos Humanos (Responsável: Responsável de Recursos Humanos);<br/>         Processo de Gestão de Materiais (Responsável: Responsável de Manutenção).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>3º<br/>NÍVEL</b> | <p><b>Procedimentos</b><br/>Documentos que dizem respeito a uma área funcional da organização, e que desenvolvem e indicam, passo a passo, os métodos operativos, os intervenientes e a forma como se realiza a sua intervenção:<br/>         Procedimento de Controlo documental;<br/>         Procedimento de Não Conformidades, Reclamações e ações corretivas;<br/>         Procedimento de Auditorias;<br/>         Procedimento Avaliação de Aspetos e Impactos Ambientais;<br/>         Procedimento Gestão de Produtos Químicos;<br/>         Procedimento da Consulta e Participação dos Trabalhadores;<br/>         Procedimento de Identificação de Perigos e Controlo dos Riscos Ocupacionais;<br/>         Procedimento de Controlo Operacional dos Perigos e Riscos para a SST;<br/>         Procedimento de Organização e acompanhamento dos Serviços de SST e Medicina do trabalho;<br/>         Procedimento de Controlo e Gestão de Máquinas e Equipamentos de Trabalho;<br/>         Procedimento da Gestão de Emergência;<br/>         Procedimento de Investigação de Incidentes de Trabalho e Doenças Profissionais;<br/>         Procedimento para Avaliação e qualificação de fornecedores;<br/>         Procedimento de Gestão de Sugestões/Reclamações;<br/>         Gestão de Recursos de Medição e Monitorização;<br/>         Procedimento para Colagem da Sola ao Corte.</p> <p><b>Planos de Controlo</b><br/>Documentos que especificam quais as metodologias de controlo e recursos associados a aplicar, por quem e quando:<br/>         Plano de Comunicação;<br/>         Plano de Gestão dos Indicadores e Objetivos dos Processos;<br/>         Plano Anual de Atividades do SGI;<br/>         Plano de Melhoria;<br/>         Programa de formação;<br/>         Plano e livrete de Manutenção;<br/>         Plano de calibração RMM.</p> |
| <b>4º<br/>NÍVEL</b> | <p><b>Registo</b><br/>Documento que expressa resultados obtidos ou fornece evidência das atividades realizadas.</p> <p><b>Impresso</b><br/>Todo o documento, com um dado formato, que serve de suporte para os documentos e registos do SGI.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

Este processo implicou a atualização da respetiva documentação, de forma a garantir a conformidade com os requisitos estabelecidos pela norma NP ISO 45001:2019, assim como a elaboração de novos documentos para suprir as lacunas detetadas.

A revisão documental foi conduzida de forma faseada, priorizando os documentos chave do SGI, tais como: o Manual de Gestão do SGI e o Manual de Funções, tendo sido incorporados os aspetos relevantes da SST, alinhando-os com os requisitos da NP ISO 45001:2019. Simultaneamente, a documentação que descreve o contexto da organização e as necessidades e expectativas das partes interessadas foi atualizada, considerando os mesmos aspetos. Os processos e procedimentos do SGI foram também analisados e atualizados, tendo sido incluídos os aspetos relacionados com a gestão de riscos ocupacionais, a promoção da saúde e segurança dos trabalhadores e o cumprimento dos requisitos legais e outros requisitos em matéria de SST.

Os Planos de Controlo foram atualizados de acordo com as metodologias de controlo, os recursos a serem alocados, os responsáveis pela sua implementação e os prazos a serem cumpridos no âmbito do SGSST.

Por fim, os modelos de registo e impressos foram revistos e atualizados, em conformidade com os novos requisitos e procedimentos elaborados no âmbito do SGSST.

Desta forma, após a conclusão desta fase de desenvolvimento documental, o sistema de gestão integrado da Qualidade, Ambiente e Segurança encontrou-se devidamente estruturado, dispondo de todos os suportes necessários para o cumprimento dos requisitos da norma e da operacionalização do mesmo.

### Verificação final

Posteriormente, foi novamente aplicada a lista de verificação da NP ISO 45001:2019, com intuito de verificação do cumprimento dos requisitos, tendo em consideração a conformidade da base documental revista e elaborada do sistema. A análise detalhada dos resultados da verificação final, realizada após a conclusão da etapa anterior, apresenta-se através da tabela 3, que demonstrou a existência de um aumento expressivo na conformidade geral com os requisitos do respetivo normativo, com 30 requisitos (87%) a atingirem o patamar de plena conformidade. Contudo, a análise também revelou que 7 requisitos (13%) ainda se encontram em conformidade parcial. Esta constatação sublinha a necessidade de se desenvolver e/ou aprimorar informações documentadas adicionais, assim como a operacionalização e obtenção de determinados registos, de modo obter resultados para os indicadores de desempenho.

**Tabela 3.** Lista de Verificação Final da NP ISO 45001:2019. (Fonte: Autor, 2024)

| Nível | Total | 4. Contexto da organização | 5. Liderança e participação dos trabalhadores | 6. Planeamento | 7. Suporte | 8. Operacionalização | 9. Avaliação do desempenho | 10. Melhoria |
|-------|-------|----------------------------|-----------------------------------------------|----------------|------------|----------------------|----------------------------|--------------|
| C     | 87%   | 3                          | 2                                             | 8              | 6          | 7                    | 4                          | 3            |
| CP    | 13%   | 1                          | 2                                             | 0              | 1          | 0                    | 1                          | 0            |
| NC    | 0%    | 0                          | 0                                             | 0              | 0          | 0                    | 0                          | 0            |

**Legenda:** C – Conforme CP - Conforme parcial NC - Não conforme

Este salto qualitativo passou pela definição do contexto da organização, a identificação de perigos e a avaliação de riscos ocupacionais, o estabelecimento de objetivos e indicadores, a elaboração de procedimentos de operacionalização, da gestão de recursos e da comunicação interna e externa, comprovando a eficácia do trabalho desenvolvido e a capacidade da organização em assimilar e aplicar os princípios da norma.

De seguida, foi agendada/realizada uma reunião com os responsáveis do Sistema de Gestão da organização de estudo, tendo sido apresentada a Proposta do Sistema de Gestão Integrado de Qualidade, Ambiente e Segurança. A apresentação da proposta do modelo de integração concentrou-se na visão geral do SGI, dos processos, as responsabilidades, os indicadores de desempenho e as diferentes interações entre os diferentes sistemas de gestão da Qualidade e Ambiente. A aprovação dessa proposta por parte dos RQAS garante o comprometimento

das diferentes áreas da organização na implementação do SGI. Nessa foi ainda estabelecida as etapas de implementação necessárias, tendo em consideração os recursos atuais da empresa.

### **Implementação**

As ações de implementação consistiram na aplicação: do Procedimento de Identificação de Perigos e Controlo dos Riscos Ocupacionais, da análise da conformidade legal e de outros requisitos da empresa em matéria de segurança e saúde do trabalho, do Procedimento de Controlo Operacional dos Perigos e Riscos para a SST e dos procedimentos de Gestão de Produtos Químicos.

### **Identificação de Perigos e Controlo dos Riscos Ocupacionais**

Nesta etapa inicial, procedeu-se à aplicação do método MARAT para a identificação de perigos e a avaliação dos riscos ocupacionais presentes na organização. Este processo foi conduzido de forma abrangente, envolvendo todos os intervenientes relevantes nos processos produtivos, nomeadamente os encarregados de linha, a gestão de topo e os próprios colaboradores. Ao todo foram envolvidos no estudo de projeto os 80 colaboradores da empresa.

Foram realizadas também entrevistas com os respetivos intervenientes, o levantamento exaustivo de equipamentos e máquinas de trabalho, produtos químicos potencialmente perigosos e equipamentos de proteção individual (EPIs) já utilizados pelos colaboradores da empresa. Adicionalmente, foram realizadas observações diretas dos postos de trabalho e de determinadas tarefas ocasionais, mas consideradas relevantes para a avaliação dos riscos profissionais.

A abordagem mista adotada, que combinou entrevistas, levantamentos e observações, permitiu obter uma visão completa sobre os riscos ocupacionais presentes na organização, garantindo assim a identificação dos perigos existentes nos locais de trabalho e uma avaliação dos riscos de forma mais rigorosa e abrangente.

Deste modo com a aplicação da metodologia referida, foram identificados um total de 146 riscos ocupacionais presentes na organização de estudo. A análise detalhada dos resultados revelou que a grande maioria dos riscos (108) está enquadrada no nível de intervenção III ou IV, indicando um nível de controlo satisfatório ou uma perigosidade reduzida. No entanto, a avaliação de riscos ocupacionais também evidenciou a existência de 3 riscos classificados no nível de intervenção I, o que exige uma ação imediata para eliminar ou controlar estes riscos, dada a sua elevada probabilidade de causar danos graves ou fatais aos trabalhadores.

Os riscos classificados no nível de intervenção I consistem na exposição ao Ruído na Máquina de Cardar e no Martelo Pneumático, na linha da montagem, e na exposição ao Ruído nas Máquinas de Meter Ilhós, Ribetes, Ganchos e Molas, na linha da costura, onde os respetivos postos de trabalho excedem os 87 dB(A).

As ações preventivas / corretivas aplicadas na empresa, com o intuito de controlar o risco da exposição do ruído, passam pela manutenção na máquina ou equipamento de trabalho e garantir a utilização de protetores auriculares por todos os trabalhadores que utilizem esta máquina. É garantida também a avaliação da capacidade auditiva anual e a rotatividade dos trabalhadores nesses postos de trabalho.

### **Análise da Conformidade Legal**

A análise da legislação aplicável à segurança e saúde no trabalho iniciou-se com o levantamento exaustivo dos diplomas legais aplicáveis com a realidade da organização e do tipo de atividade da mesma, consultando-se para este efeito o Diário da República e o portal da Autoridade para as Condições do Trabalho (ACT).

Posteriormente, procedeu-se à análise detalhada de cada diploma, com a identificação dos artigos e demais requisitos aplicáveis e, verificando-se o cumprimento/incumprimento das exigências legais ao nível da organização de estudo.

Da análise exaustiva da legislação aplicável permitiu concluir que a empresa de estudo demonstra um nível satisfatório de conformidade com a maioria dos requisitos legais. No entanto, a análise também revelou áreas onde a empresa pode estar em risco de incumprimento, o que exige uma iniciativa da empresa em estabelecer medidas para combater essas situações e garantir a conformidade legal.



As não conformidades detetadas centram-se na:

- Formação dos representantes do empregador não existente (Lei n.º 102/2009, de 10 de setembro);
- Avaliação de Riscos Ergonómica não existente (Decreto-Lei n.º 330/93, de 25 de setembro);
- Verificação de Segurança de Máquinas e Equipamentos de Trabalho, de acordo com o Decreto-Lei n.º 50/2005, de 25 de fevereiro encontra-se desatualizada (Decreto-Lei n.º 50/2005, de 25 de fevereiro).

### **Controlo Operacional dos Perigos e Riscos para a SST**

No âmbito do SGSST proposto foi ainda elaborado um Procedimento de Controlo Operacional dos Perigos e Riscos para a SST, que dá cumprimento ao requisito 8.1.2. (Eliminação dos perigos e redução dos riscos para a SST). Este estabelece a metodologia para o controlo operacional dos perigos e riscos identificados no âmbito do SGSST, de forma a garantir que as medidas de controlo implementadas sejam eficazes na eliminação dos perigos e na redução dos riscos a níveis aceitáveis.

Seguindo o respetivo procedimento, foram procedidas avaliações de riscos específicas, com o intuito de verificar a existência de riscos físicos na organização e, caso aplicável, que medidas serão necessárias de implementar.

### **Controlo Operacional dos Perigos e Riscos para a SST - Conforto Térmico**

Numa fase inicial do presente projeto, foi detetada a necessidade de se proceder a uma avaliação de conforto térmico na empresa de estudo. Deste modo, no início do ano de 2024, foi realizada uma avaliação de conforto térmico nos postos de trabalho onde se verificou a necessidade de proceder à respetiva avaliação: na secção da Costura e nos Armazéns.

Com base nos resultados obtidos na avaliação realizada, verificou-se que os postos da secção do armazém, apresentaram valores médios de temperatura abaixo do valor recomendado na legislação aplicável e o resultado obtido pela determinação do índice PMV-PPD, foi de sensação térmica ligeiramente fria para os postos administrativos, demonstrando desconforto térmico. O resultado obtido no posto de trabalho da secção da costura, no transportador, foi de sensação térmica ligeiramente quente, demonstrando desconforto térmico.

No posto de trabalho da secção de costura e nos postos de trabalho do armazém onde existe movimentação manual de cargas, o resultado obtido foi de sensação térmica neutra, demonstrando assim a existência de conforto térmico.

Com base nestes resultados, considerou-se que não existia a necessidade de alterações estruturais, uma vez podia-se considerar a possibilidade de ligar o ar condicionada na zona de produção, de forma a garantir o conforto térmico dos colaboradores da empresa.

### **Controlo Operacional dos Perigos e Riscos para a SST - Ruído Ocupacional**

A avaliação de riscos de ruído ocupacional seguiu a metodologia definida na legislação aplicável e, com esta, foi possível verificar que 5 colaboradores da empresa se encontram expostos ao ruído. Foi verificado também na respetiva avaliação:

- 8 postos de trabalho com valores superiores ao nível de ação inferior e inferiores ao nível de ação superior ( $80 \text{ dB(A)} \leq \text{LEX}$ ,  $\text{Te} < 85 \text{ dB(A)}$  e  $135 \leq \text{LCpico} < 137 \text{ dB(C)}$ );
- 3 postos de trabalho com exposição a níveis de ruído superior ao valor de ação superior e inferior ao valor limite de exposição ( $85 \text{ dB(A)} \leq \text{LEX}$ ,  $\text{Te} < 87 \text{ dB(A)}$  e  $135 \leq \text{LCpico} < 137 \text{ dB(C)}$ );
- 2 postos de trabalho com valores superiores ao valor limite de exposição ( $\text{LEX}_{8h} \geq 87 \text{ dB(A)}$  e  $\text{LCpico} \geq 135 \text{ dB(C)}$ ).

O controlo das fontes de ruído identificadas na avaliação de ruído ocupacional é assegurado pela respetiva empresa, através das habituais intervenções nas máquinas e equipamentos ruidosos, na vigilância da saúde e os respetivos exames médicos, e na organização do trabalho (rotatividade de postos de trabalho e colaboradores) e distribuição de equipamentos de proteção individual auditivo (auriculares e abafadores).

### **Controlo Operacional dos Perigos e Riscos para a SST - Iluminância nos postos de trabalho**

Na mesma altura, foi realizada a avaliação de iluminância nos postos de trabalho da respetiva empresa, seguindo a metodologia definida pelo normativo de referência. Nas avaliações de iluminância anteriores, verificou-se que apenas os postos de trabalho administrativos, incluindo o da zona de armazenagem, onde as atividades são predominantemente realizadas em computador, bem como nas áreas sociais, apresentavam valores de iluminância inferiores aos recomendados. Para resolver estas situações, no final de setembro de 2024, a iluminação dos respetivos postos de trabalho foi reforçada, através da instalação de novas luminárias. Considerando os resultados obtidos no respetivo período de avaliação do risco, verificou-se que os postos de trabalho administrativos, incluindo o da zona de armazenagem, e as áreas, apresentam agora os valores de iluminância recomendados pela norma aplicável.

### **Gestão de Produtos Químicos**

No âmbito do respetivo SGSST desenvolvido, existe o Procedimento Gestão de Produtos Químicos, que estabelece uma metodologia para a gestão dos produtos químicos utilizados pela empresa, aplicado a produtos químicos utilizados no processo produtivo, limpeza e manutenção. Assim, procedeu-se à atualização do Inventário de Produtos Químicos, com os produtos químicos utilizados pela empresa em 2024. Os dados dos produtos químicos existentes na empresa, assim como as respetivas fichas de dados de segurança, foram fornecidos pelo responsável do Armazém de matérias-primas.

Após a recolha da respetiva informação sobre os produtos químicos e a atualização do respetivo documento, foi possível verificar que a empresa não tem, à data do presente projeto, nenhum produto químico CMR. Isto deve-se ao facto, processo de substituição os seus produtos químicos com substâncias identificadas como CMR ao longo dos últimos anos, tendo encontrado outras soluções e produtos químicos de base aquosa ou, pelo menos, sem as substâncias CMR, através da pesquisa de mercado e reuniões com os respetivos fornecedores. O controlo na receção dos vários produtos químicos feitos pelos respetivos responsáveis demonstrou-se essencial também para uma melhor gestão dos mesmos e de produtos considerados não conformes.

### **Limitações**

O presente estudo de projeto apresentou vários desafios e limitações, devido não só ao contexto da empresa alvo de estudo, mas também devido ao tema em si. Como principais limitações refere-se: A revisão da literatura revelou-se um desafio, não devido à escassez de artigos e outros trabalhos científicos com o tema de Sistemas de Gestão Integrados ou sobre a SST e o respetivo sistema de gestão de SST com base do normativo da NP ISO 45001:2019, mais sim devido à escassez dos mesmos em empresas do setor do calçado em casos de estudo; A integração de todos os requisitos da norma NP ISO 45001:2019 num sistema já consolidado, sem o sobrecarregar a nível documental e até mesmo ao nível da atribuição de responsabilidades, e sem comprometer a sua funcionalidade futura, constituiu uma tarefa complexa, exigindo assim algum planeamento adicional; Por fim nas etapas de operacionalização do SGI com o SGSST, que foram afetadas por determinadas restrições contextuais que limitaram a disponibilidade da empresa para dedicar o seu tempo e recursos ao projeto. As instabilidades do mercado e a necessidade de priorizar a produção em massa de encomendas para clientes resultaram na escassez de recursos humanos e financeiros para a implementação plena do SGSST, conforme planeado no cronograma de implementação da NP ISO 45001:2019.

### **Conclusões**

Com base nos resultados obtidos da revisão da literatura, diversos autores constataram também que as empresas e consumidores estão cada vez mais preocupados em garantir requisitos de segurança e saúde no trabalho, indo à procura de garantias de conformidade e melhoria.

Na fase inicial, cumprindo com o objetivo “Diagnosticar as condições de SST na organização”, foi realizado uma vistoria à empresa, com o intuito de caracterizar as condições de SST. Com a vistoria, foi possível concluir

que a empresa cumpre com os requisitos legais aplicáveis à segurança e saúde no trabalho nas instalações industriais.

A verificação inicial dos sistemas de gestão existentes de acordo com a NP ISO 45001:2019, demonstrou que a organização cumpria parcialmente com 79% dos requisitos, 8% estavam em conformidade e 13% não conformes. Uma segunda verificação, de caráter final, foi então realizada, com o propósito de se verificar a adequação da documentação elaborada e o seu grau de cumprimento em relação aos requisitos da norma. Esta etapa de verificação permitiu assegurar a solidez e a conformidade do SGSST proposto. Inicialmente, a verificação inicial evidenciava um cenário de conformidade parcial, com apenas 3 requisitos (8%) em total conformidade e 5 (13%) em não conformidade. A análise detalhada dos resultados da verificação final, realizada após a conclusão da etapa anterior, demonstrou um aumento expressivo na conformidade dos requisitos do respetivo normativo, com 30 requisitos (87%) a atingirem o patamar de plena conformidade.

Deste modo, foi possível verificar que os objetivos previamente estabelecidos do presente trabalho de projeto foram atingidos. A proposta do Sistema de Gestão Integrado de Qualidade, Ambiente e Segurança, permitiu à empresa um conhecimento alargado dos requisitos da norma NP ISO 45001:2019, permitindo assim o desenvolvimento de uma cultura de segurança proativa e, em outros campos, um elemento de distinção no mercado onde se insere, beneficiando a sua imagem no mesmo.

Os resultados alcançados mostram avanços consideráveis em direção à conformidade do respetivo normativo e à promoção de uma cultura de segurança no trabalho, evidenciando o potencial do SGI proposto e parcialmente implementado como ferramenta estratégica para a melhoria do desempenho global da organização em várias vertentes, principalmente na área da segurança e saúde do trabalho. Sendo que este também tem potencial para ser adaptado/replicado em organizações similares à da empresa de estudo, no setor do calçado.

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# **SISTEMA DE GESTÃO DA SEGURANÇA E SAÚDE NO TRABALHO (NP ISO 45001:2019): PROPOSTA DE MODELO DE GESTÃO NUMA EMPRESA DO SETOR ALIMENTAR**

## **OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT SYSTEM (NP ISO 45001:2019): PROPOSAL FOR A MANAGEMENT MODEL IN A FOOD SECTOR COMPANY**

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### **Abstract**

Nowadays, it is essential for companies to be concerned with occupational health and safety. The main objective is to develop a proposal for SGSST, according to the normative framework NP ISO 45001:2019, for a company in the food sector and demonstrate its relevance so that it can later be implemented in the organization. To conduct an initial diagnosis, a questionnaire was applied to all employees. A checklist was created in the initial phase to understand the context and the initial status of the management system at the organizational level. Based on the diagnosis, an action plan was developed with improvement measures to be adopted regarding documented information. After processing and analysing the questionnaires, it was found that the majority of the responses were unanimous, concluding that there is awareness/knowledge about the topic. Regarding the diagnosis of the existing conditions, a significant number of non-conformities were detected, which led to the creation of several documents necessary to comply with the SGSST requirements. The proposed management system will enable the organization to improve productivity and gain competitiveness in the markets through cost reduction, allowing the organization to improve working conditions, making them safer and healthier.

**Keywords:** Management System; Health and Safety at Work; Risk Management; NP ISO 45001: 2019.

### **Resumo**

Hoje em dia é fundamental que as empresas se preocupem com a segurança e saúde no trabalho. O principal objetivo é realizar uma proposta de SGSST, de acordo com o referencial normativo NP ISO 45001:2019 numa empresa do setor alimentar e demonstrar a sua relevância para que posteriormente, este seja implementado na organização. Para realizar um primeiro diagnóstico, foi aplicado um questionário a todos os colaboradores. Foi elaborada uma lista de verificação na fase inicial para compreender o contexto e o estado inicial do sistema de gestão ao nível da organização. Com base no diagnóstico efetuado foi elaborado um plano de ações com as medidas de melhoria adotar no âmbito da informação documentada. Após tratamento e análise dos questionários, constatou-se que a maioria das respostas foram unânimes, concluindo-se que existe perceção/conhecimento sobre o tema. Quanto ao diagnóstico das condições existentes, detetou-se um número significativo de não conformidades, o que levou à elaboração de diversos documentos necessários para cumprimento dos requisitos ao SGSST. O sistema de gestão proposto permitirá à organização melhorar a produtividade e obter ganhos de competitividade nos mercados através da redução de custos, que permite à organização a melhoria das condições de trabalho, tornando-as mais seguras e saudáveis.

**Palavras-chave:** Sistema de Gestão; Segurança e Saúde no Trabalho; Gestão de Risco; NP ISO 45001:2019.

### **Introdução**

Atualmente as organizações, com a necessidade de se tornarem mais rentáveis e sustentáveis, com o aumento da globalização e internacionalização, com perspetiva de serem mais competitivas e eficientes em relação aos seus concorrentes, têm apostado no desenvolvimento de sistemas de gestão que vão ao encontro das necessidades e preocupações dos trabalhadores e das restantes partes interessadas (Pires, 2016).

Com os avanços da tecnologia nos dias de hoje as empresas procuram ter uma excelência organizacional, pois, no quotidiano lidam com diversos *Stakeholders* (colaboradores, clientes, estado e entre outros) sendo necessário cumprir os seus requisitos (necessidades e expectativas).

Para tal, as organizações devem ter um controlo sobre os processos, serviços, produtos ou atividades que tenham impacto no ambiente de trabalho e, naturalmente, na Segurança e Saúde Ocupacional dos trabalhadores. A forma mais estruturante de o alcançar é através da implementação de um Sistema de Segurança e Saúde no trabalho, uma vez que as pessoas são a maior riqueza de qualquer organização (Santos, Almeida, Ramos, & Carvalho, 2018).

No caso do Sistema de Gestão de Segurança e Saúde no Trabalho (SGSST), uma correta implementação e gestão eficaz é reconhecida por todas as partes interessadas internas e externas à organização.

A gestão como conceito é relativamente antiga, mas o seu estudo é um fenómeno com pouco menos que um século. O estudo da gestão é a história da evolução de um conjunto de concepções da natureza do homem, trabalho e forma de funcionar das organizações (Lisboa, Coelho, Coelho, & Almeida, 2013).

O sistema de gestão permite definir os processos estratégicos, operacionais e de suporte. Nos processos verifica-se e identifica-se as causas dos problemas, procurando encontrar as soluções mais adequadas de coordenação entre as diversas áreas de gestão das empresas por forma a alcançar a melhoria contínua, que se encontra sempre subjacente a estes sistemas.

O presente trabalho de projeto tem como objetivo principal desenvolver uma proposta de um modelo de SGSST segundo a NP ISO 45001:2019 numa empresa do setor alimentar, esperando-se que após a apresentação da proposta modelo a empresa o venha a implementar.

Para que o objetivo principal seja conseguido coexistem também objetivos secundários que se pretendem atingir, nomeadamente:

- Efetuar um diagnóstico ao estado de documentação e das condições ao nível da SST na organização de estudo;
- Elaborar um plano de intervenção constituído por linhas de orientação e estruturas documentais com necessidade de reestruturação ou elaboração;
- Elaborar um documento tendo em vista a NP ISO 45001:2019, entre elas Política de Segurança, objetivos de SST, Partes interessadas, riscos/oportunidades e de outros elementos do sistema de gestão.

## Revisão da literatura

A Segurança e Saúde no Trabalho (SST) surge como um fenómeno que decorre da história do trabalho, principalmente do lado negro dessa história. Não se afirma como um pressuposto inicial, mas como uma necessidade social que foi emergindo devido aos confrangimentos que o exercício ocupacional acarretou para o bem-estar do ser humano (Neto, 2011).

O caminho para a SST inicia-se com o relatório do Comité Britânico de SST sobre o ponto da situação da Segurança e Saúde no Trabalho, apresentado em 1972 (Relatório Robens, RU). Anos mais tarde, considerou-se que os modelos de gestão empresarial constituídos para assegurar uma resposta rápida às oscilações da situação através de uma avaliação continua do desempenho, eram modelos possíveis para o desenvolvimento de uma abordagem sistémica para a gestão de SST.

Em 2001 a Organização Internacional do Trabalho OIT publicou as linhas de orientação para os SGSST “Guidelines on Occupational Safety and Health Management Systems – OIT – OSH 2001”, com o objetivo de melhorar as condições de trabalho, diminuir as doenças profissionais, os incidentes e acidentes de trabalho nas organizações.

De forma a conciliar num só sistema aspetos relativos à qualidade, ambiente e SST a OHSAS 18001:1999 sofreu uma reestruturação tendo sido substituída em julho de 2007 pela OHSAS 18001:2007. Este referencial estabelece os requisitos que devem ser tidos em conta para um SGSST de forma a controlar riscos e a melhorar o



desempenho nesta área. Entretanto, só em março de 2018 foi publicada pela Organização Internacional de Normalização uma nova norma aplicada à gestão de sistemas de segurança e saúde no trabalho, a ISO 45001. A nova norma ISO 45001:2018 foi desenvolvida para dar resposta ao progresso da consciência dos trabalhadores e as crescentes expectativas da sociedade em relação ao objeto da SST que obrigam as organizações a perspetivar importantes mudanças e implementar processos eficazes que permitam reduzir o número de acidentes e consequentes custos (Pinto, 2019). A aplicação do sistema de gestão em conformidade com a norma ISO 45001:2018 permite à organização tornar-se mais eficiente e eficaz a gerir os riscos e oportunidades permitindo uma otimização do desempenho da SST (Pinto, 2019).

De acordo com Santos, *et al* (2018), o normativo ISO 45001:2018 pode ser implementado em qualquer tipo de organização, independentemente da sua dimensão, tipo e natureza. A totalidade dos requisitos deve fazer parte integrante dos próprios processos de gestão de uma organização.

Deste modo considera-se que a NP ISO 45001:2018 é uma mais-valia para a melhoria da segurança e saúde dos trabalhadores pois contribui para eliminar/reduzir os riscos ocupacionais e melhorar as condições de trabalho nas organizações.

Em 2019 surgiu o normativo NP ISO 45001:2019 pelo IPQ que no fundo é uma tradução para português do normativo original que foi publicado inglês.

Nos últimos anos, o reconhecimento da importância da segurança começou a aumentar (Serran e Alberton, 2024), embora, os acidentes de trabalho, doenças e lesões continuem a ser um grande problema nas organizações.

Em maio de 2021, a Organização Mundial de Saúde - OMS e a OIT publicaram os resultados preliminares do estudo que quantificou o peso das doenças cardiovasculares, que evidenciou exposição a horas de trabalho como causa atribuível a 750 000 óbitos. No relatório observa-se que o peso total das doenças relacionadas com o trabalho é provavelmente muito mais elevado, uma vez que as perdas de saúde relacionadas com vários outros fatores de risco profissional devem ainda ser quantificadas no futuro (Organização Internacional do trabalho, 2021).

De acordo com estimativas recentes publicadas pela OIT, todos os anos, 2,78 milhões de trabalhadores morrem devido a acidentes de trabalho e doenças profissionais (2,4 milhões dos quais devido a doenças) e 374 milhões de trabalhadores são vítimas de acidentes de trabalho não fatais (Organização Internacional do Trabalho, 2019). Segundo o diretor-geral da OIT refere que "estas estimativas fornecem informações importantes quanto ao peso das doenças relacionadas com o trabalho, e esta informação pode ajudar a moldar políticas e práticas para criar locais de trabalho mais saudáveis e seguros" (Organização Internacional do trabalho, 2021, p.1).

De acordo com o Internacional Labour Office, a cada 15 segundos um trabalhador morre num acidente de trabalho ou doença relacionada e 153 trabalhadores sofrem acidente de trabalho. Esta estatística demonstrou ainda que mais de 2,3 milhões de trabalhadores morrem anualmente devido a acidentes de trabalho ou doenças ocupacionais. Além disso, nos últimos anos, a perceção de risco mudou substancialmente, bem como o contexto macroeconómico no qual as organizações devem atuar (Neag, Ivascu, & Draghici, 2019).

No relatório Data & Trends 2020 da FoodDrinkEurope verifica-se que a indústria alimentar e de bebidas da União Europeia emprega 4,82 milhões de pessoas, sendo considerado o maior empregador industrial em metade dos Estados-Membros da União Europeia (FoodDrinkEurope, 2020). O que evidencia a existência de um valor significativo de trabalhadores neste setor e consequente exposição a fatores de risco ocupacionais associados à natureza das atividades deste.

Em muitos países, foram adotados códigos de segurança e saúde para o setor alimentar para complementar a legislação de segurança e saúde, para que os colaboradores estejam em condições de identificar os problemas de SST e sugerir soluções. Posto isto é importante que os empregadores e os colaboradores do setor alimentar possam contribuir e manter os conhecimentos e competências para melhorar as questões de segurança e saúde no trabalho. Os colaboradores do setor alimentar podem sentir fadiga e desconforto ao realizar tarefas altamente repetitivas, trabalhando em posturas recorrentes e erradas, realizando trabalhos físicos pesados e a fazer grandes esforços. Estes tipos de trabalhos prolongados sob estas condições podem resultar em lesões crônicas nos

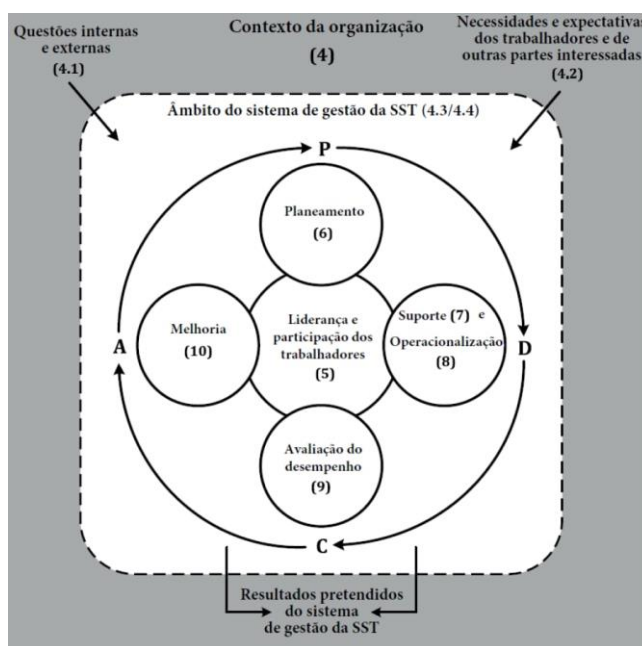
músculos, tendões, ligamentos, nervos e vasos sanguíneos. Estas lesões podem aumentar os custos para a organização que podem incluir serviços médicos, prémios de compensação de trabalhadores, rotatividade de funcionários e absentismo. A produtividade, qualidade do produto e moral dos colaboradores também podem sofrer (Silva, *et al*, 2024). Uma maneira de reduzir estas lesões e minimizar os outros problemas de SST no setor alimentar é o de aplicar intervenções ergonómicas no local de trabalho. A ergonomia é o estudo de como melhorar o ajuste entre as tarefas dos postos de trabalho e os colaboradores que executam as obras (Kim, 2015). Com a implementação de um SGSST, as empresas conseguem ter uma redução dos riscos de acidentes e doenças profissionais, tendo também outros benefícios para a organização nomeadamente (Santos, Almeida, Ramos, & Carvalho, 2018):

- Melhoria da imagem da organização;
- Redução de prémio de seguros de acidentes e doenças profissionais;
- Melhoria da produtividade;
- Bem-estar mental e físico dos colaboradores;
- Eliminação de sanções por incumprimento da legislação.

Segundo a NP ISO 45001:2019, o objetivo de um SGSST é proporcionar uma estrutura para gerir os riscos e as oportunidades para a SST, tendo como objetivo e resultado prevenir lesões e afeções de saúde relacionadas com o trabalho e proporcionar locais de trabalho seguros e saudáveis.

O SGSST é uma ferramenta de gestão que contribuiu para a melhoria do desempenho das empresas no que diz respeito às questões de SST que é uma necessidade fundamental para as organizações, para os trabalhadores e para a sociedade em geral, uma vez que permite melhorar o desempenho de uma organização no âmbito da saúde e segurança (Wachter & Yorio, 2014).

O desenvolvimento e funcionamento de um SGSST assenta no princípio do Ciclo Deming “Planificar-Desenvolver-Verificar-Ajustar” (PDVA) ou PDCA em inglês Plan – Do – Check- Act, conforme evidência a Figura 1, concebido nos anos 20 para verificar o desempenho de empresas numa base de continuidade. O Ciclo PDCA, é uma ferramenta de gestão muito utilizada pelas empresas em todo o mundo. Este sistema foi concebido por Walter A. Shewhart e amplamente divulgado por Willian E. Deming, na década de 50, que consiste em planear, executar, avaliar/estudar e atuar corretivamente e/ou preventivamente de modo que a organização possa obter resultados cada vez melhores, relativamente aos seus indicadores de SST.



**Figura 1.** Ciclo PDCA (Norma NP ISO 45001:2019)

De acordo com Ambi 22-Estudos e Projectos Ambiente Lda (2018, p.5), considera que “um sistema deste tipo permite a uma organização desenvolver uma política de SST, estabelecer objetivos e processos para atingir os compromissos da política, desenvolver ações necessárias para melhorar o respetivo desempenho, demonstrar a conformidade do sistema com os requisitos da presente Norma e dar suporte e promover boas práticas de SST, em equilíbrio com as questões socioeconómicas”.

O SGSST atualmente assume um papel estratégico no desenvolvimento da política, na prevenção, na produtividade, na imagem e na competitividade das organizações.

### **Materiais e Métodos**

O presente caso de estudo, foi realizado numa empresa do setor alimentar já selecionada da região Norte de Portugal que é constituída por 7 colaboradores.

Deste modo e para a concretização dos objetivos propostos ao nível do estudo, a metodologia aplicada fundamenta-se numa primeira fase na recolha de informação sustentada na pesquisa em bases de dados técnico-científicos acessíveis (Scopus, Science Direct, repositórios científicos de acesso aberto e entre outras) relativa à temática, como também junto da empresa em estudo e dos seus colaboradores. Esta também consiste na pesquisa bibliográfica sobre a documentação atual da NP ISO 45001:2019, que permita a interpretação da norma e das ações a ter em conta para o cumprimento dos requisitos.

A metodologia adotada enquadra-se na investigação/ação. Esta caracteriza-se pelo facto de se tratar de uma metodologia de pesquisa maioritariamente prática e aplicada que se gere pelas necessidades de resolver problemas reais. Existem diversas definições de investigação-ação, contudo existe um consenso no que se refere à identificação de algumas características básicas desta abordagem metodológica como refere Cardoso (2014, pp. 35-36): *“é um processo levado a efeito pelos práticos que estão envolvidos numa determinada situação, que desempenham, simultaneamente, o papel de investigadores e participantes; decorre, no local de trabalho, tendo subjacente problemas do quotidiano profissional; visa a melhoria de uma situação particular, através do diagnóstico de um problema que se pretende modificar, de imediato ou a curto prazo; implica uma estratégia reflexiva, em que o prático reflete sobre a ação a concretizar, ou seja, reflete sobre a ação antes e depois, numa visão integrada da teoria e prática”*.

Numa segunda fase foi desenvolvido e aplicado um questionário a todos os colaboradores da organização para se perceber qual o conhecimento/perceção dos mesmos em matéria de SST. Este foi dividido em três partes. A primeira parte mais direcionada para se conhecer a caracterização geral dos inquiridos, a segunda parte constituída por questões direcionadas para perceção do conhecimento destes sobre a SST e a terceira parte sobre como descrevem as instalações da organização ao nível da SST. Também com base no diagnóstico dos dados que serão recolhidos através do questionário e a fim de se verificar o estado inicial do nível de cumprimento existente da organização foi utilizada uma *check list* com os requisitos da NP ISO 45001:2019 de forma a facilitar a verificação do que está em conformidade e o que é necessário melhorar e/ou acrescentar.

Após a análise do diagnóstico inicial sobre o nível de cumprimento dos requisitos (em falta ou incompletos), inicia-se a elaboração de toda a documentação necessária para o sistema de gestão da organização dando satisfação aos requisitos do referencial normativo aplicável.

Numa terceira fase e após o desenvolvimento de toda informação documentada do sistema foi realizada novamente uma verificação com base na mesma *check list*, de forma a avaliar o estado final do sistema de gestão da SST proposto, em conformidade com os requisitos do referencial normativo.

### **Resultados e Discussão**

Foram recolhidos dados através do questionário em suporte de papel que foi aplicado a todos os membros da organização. Obteve-se respostas dos 7 colaboradores que participaram na amostra, havendo assim uma adesão total (100%) na participação do estudo.

Dos resultados obtidos com base na aplicação do questionário aos trabalhadores da empresa de estudo, verifica-se em relação à caracterização geral dos inquiridos que a maioria dos colaboradores são do sexo feminino, facto característico neste sector das atividades da indústria alimentar de transformação de carnes.

Verifica-se também que a maioria dos colaboradores tem idade compreendida entre os 46 e os 55 anos e o seu nível de habilitações literárias é igual ou inferior ao 4º ano de escolaridade. Ou seja, não existem muitos jovens a trabalhar na organização o que mais tarde pode traduzir-se em falta de recursos e escassez de mão de obra especializada, dado ainda o baixo nível de escolaridade.

Já em relação ao tempo de experiência a maioria dos colaboradores possui entre os 11 e 20 anos de experiência no exercício da profissão, o que significa que estes já têm uma significativa experiência na área em que executam os trabalhos da sua profissão/categoria profissional.

Na segunda e terceira parte do questionário, com base nos resultados obtidos e após a sua análise constata-se que na maior parte das respostas os colaboradores são unânimes em relação às condições de SST na organização, não havendo grande discrepância entre estes.

Deste modo, em geral pode-se concluir que todos os inquiridos consideram as condições de SST adotadas pela organização que são adequadas para o desenvolvimento das suas tarefas incluindo a distribuição de EPI, as medidas de proteção e prevenção para a eliminação dos riscos ocupacionais, a sinalização de emergência e prestação dos primeiros socorros. No entanto, existem questões onde as respostas não foram unânimes e que carecem de especial atenção, como o caso da relevância da formação em SST para o desempenho do trabalho de forma segura e saudável onde 14% dos inquiridos diz não saber/não responde. Outras duas questões importantes e que também não houve unanimidade de respostas foi na pressão em ambiente de trabalho (14% diz que sim) e na falta de comunicação entre colegas de trabalho e gestão de topo (29% diz que sim). Estas três questões e respetivos resultados obtidos são indicadores relevantes que devem ser ponderados pela organização de estudo, no sentido de adotar melhorias futuras que eliminem/mitiguem os seus efeitos no contexto desta.

É de salientar ainda o facto de nenhum dos inquiridos ter sido vítima de acidente de trabalho, o que leva a concluir que embora a organização não possua um SGSST, as tarefas estão a ser bem desempenhadas e as medidas de proteção adotadas estão a ser suficientes face aos dados obtidos. Não obstante, deve ser tida sempre em conta a realização de uma avaliação de riscos ocupacionais, de modo que caso seja identificado um novo risco o mesmo seja eliminado ou mitigado com a tomadas de medidas de prevenção e proteção. Por forma a que a organização em relação à sinistralidade laboral continue a manter a meta dos zero acidentes.

Quanto às questões relacionadas com o nível das condições de trabalho, higiene e limpeza, ambiente térmico, iluminação, segurança de máquinas e equipamentos de trabalho e da carga horária na organização, as respostas situaram-se entre o muito bom e o bom. O que significa que existe uma perceção positiva destes em relação a estas áreas, o que é aceitável face aos resultados obtidos no decorrer do trabalho.

Ao nível das sugestões de melhoria das condições de trabalho na organização em estudo não foram obtidas respostas da parte dos colaboradores desta. Provavelmente pelo sentimento positivo e de confiança destes em relação à organização.

Embora a organização não possua nenhum SGSST (apenas um serviço externo de SST) verifica-se que os colaboradores desta têm conhecimento nesta área e da sua importância no contexto laboral. No entanto deverão ser realizadas ações de formação ao nível da SST para consolidar o conhecimento e perceção já evidenciada pelos colaboradores com a frequência destas ajustada às necessidades da organização, seguindo o definido pela legislação laboral. Ou sempre que se verifique que existe alguma alteração necessária que exige dar formação (ex.: mudança do posto de trabalho, alteração do processo produtivo, adoção de nova tecnologia e de novos equipamentos de trabalho ou alteração dos existentes e entre outras).

Dos resultados obtidos com aplicação da *checklist* de verificação inicial e da respetiva análise foi possível verificar o estado da organização ao nível dos requisitos do referencial normativo NP ISO 45001:2019 em matéria de SST. Também foi possível analisar a informação documentada existente que deve ser melhorada ou mesmo desenvolvidos novos documentos, para ser possível a implementação de um SGSST. Deste modo, constatou-se que o único requisito que está em conformidade é o 8.2 (Preparação e resposta de emergência), 7

requisitos em conformidade parcial, a informação documental existente não satisfaz na íntegra os requisitos e que a larga maioria dos requisitos não possui qualquer documentação pelo que está em situação de não conformidade.

Após a primeira verificação foi identificada a principal base documental necessária para o sistema de gestão. De seguida foram efetuadas ações e desenvolvidos documentos que estavam em falta ou incompletos, como a política, a matriz de riscos e procedimentos que devem fazer parte e respetivos registos (incidentes, ação corretiva, formações...), tendo também sido ainda elaborado um plano de contingência da Covid-19.

Cada um dos documentos que foram desenvolvidos têm significativa relevância para o sistema de gestão, de forma a cumprir os requisitos do referencial normativo aplicável.

Para que a informação documentada, após aprovada pela gestão de topo seja aplicada, comunicada e difundida na organização e partes interessadas relevantes para o sistema de gestão é primordial a seleção/designação de um responsável pelo sistema que fica subordinado à gestão de topo. Este terá a incumbência/responsabilidade de passar a informação relevante às referidas partes interessadas para interação destas com o sistema de gestão da organização. No caso das partes interessadas externas deve ser comunicada a informação através de email e/ou do site da organização, por forma a chegar às partes interessadas relevantes para o sistema. Já às partes interessadas internas deve ser através de reuniões, distribuição de diretrizes e afixação da informação.

Após o desenvolvimento da principal informação documentada do sistema de gestão, segundo os requisitos do normativo aplicável, foi realizada uma nova verificação à base documental do sistema com recurso à *checklist* que foi utilizada no diagnóstico inicial. Tendo-se constatado que enquanto no início só existia um único ponto que estava em conformidade e 44 não conformidades, com a elaboração da referida documentação verifica-se que existem 44 requisitos que já se encontram em conformidade e zero não conformidades com as respetivas exigências normativas aplicáveis.

O sistema de gestão proposto permitirá também à organização de estudo melhorar a produtividade e alcançar ganhos de competitividade nos mercados mediante a redução dos custos com a melhoria dos processos em geral, com enfoque na gestão do risco e que vão contribuir para a melhoria contínua, o que permite à organização dispor de locais de trabalho mais seguros e saudáveis.

### **Limitações**

No decurso do estudo de projeto foram identificadas várias limitações diretas e indiretas ao nível organizacional e que se destacam: O facto de a organização não possuir qualquer tipo de informação e documentação; recentemente trocaram de empresa prestadora de serviços externos de SST o que não facilitou a nível de documentação que tivessem já elaborado; a gestão de topo está bastante tempo ausente o que não facilitou a comunicação/interação e envolvimento; o facto de estarem também numa altura com bastante trabalho e com agravante de serem poucos colaboradores não demonstraram grande disponibilidade de participação e receptividade ao nível da sua colaboração dada a sua absorção laboral.

### **Conclusões**

A realização do presente trabalho de projeto centrou-se na apresentação de uma proposta de um SGSST que acrescente valor à entidade em estudo. Cada vez mais se verifica que a SST é essencial nas organizações uma vez que interfere na produção e rentabilidade das mesmas.

O objetivo principal e secundários deste projeto foram na sua generalidade atingidos.

Após a primeira abordagem junto da organização de estudo verificou-se ao nível de matéria de SST que apresentava inúmeras falhas sobretudo na documentação de suporte, no entanto, embora a documentação estivesse em falta, a informação no âmbito de SST era comunicada e percecionada por todos os colaboradores, como se pode constatar com os resultados obtidos com aplicação dos questionários.

Com base nos resultados obtidos com aplicação do questionário pode-se também concluir que embora não exista um SGSST implementado na organização, o facto de não existirem acidentes de trabalho significa que as medidas que a organização tem adotado nesta área estão a ser eficazes e entendidas de forma adequada pelos



colaboradores através do seu cumprimento. Através da realização da avaliação de riscos constata-se que estes em geral encontram-se mitigados/controlados.

No âmbito do sistema de gestão proposto foram elaborados os principais documentos base do SGSSST, designadamente a política, processos, procedimentos, avaliação de riscos, registos e entre outros documentos necessários para o cumprimento dos requisitos do referencial normativo NP ISO 45001:2019. Destaca-se ainda uma evolução significativa quanto ao grau de conformidade passando de 1 requisito em conformidade para 44 o que significa que 60% dos requisitos encontram-se em conformidade. Constatou-se ainda que 28 dos requisitos estão em conformidade parcial, o que evidencia a necessidade de melhorar a informação documentada destes. No final deste projeto e após apresentar os resultados obtidos à organização verificou-se que a mesma ficou recetível a todo o trabalho que foi desenvolvido e demonstrou interesse em implementar o SGSSST proposto, para posteriormente se analisar a possibilidade de certificação. Sendo que este também tem potencial para ser adaptado/replicado em organizações similares à da empresa de estudo, no setor alimentar.

### **Agradecimentos e financiamento**

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## ACTIGRAPHY IN WORKER POPULATIONS: A SHORT REVIEW OF ITS APPLICATIONS AND FINDINGS

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### Abstract

**Background:** Actigraphy is a method for monitoring sleep patterns through movement tracking, offering advantages like low cost and continuous data collection. It's useful in large-scale research and assessing sleep disturbances in real-world occupational settings. **Objective:** This study aims to evaluate the application of actigraphy in monitoring sleep quality among workers and its potential to enhance occupational health through sleep assessment. **Materials and Methods:** A literature review was conducted on studies published between 2019 and January 2025, focusing on actigraphy's use in occupational settings. Data was collected from multiple databases, adhering to PRISMA guidelines for selection and analysis. **Results and Discussion:** Workplace stress and shift work harm sleep quality, with actigraphy guiding future actions. Technological advancements like ACTman and WORK-A improved the accuracy and efficiency of sleep monitoring in these settings. **Conclusions:** Actigraphy is an effective tool for assessing workers' sleep disturbances and can potentially improve sleep quality through better work scheduling and stress management. Technological improvements enhance its reliability and application in occupational health research. **Application:** Actigraphy can be implemented in occupational health practices to monitor sleep disturbances, leading to better sleep outcomes. Its use can guide improvements in work schedules and reduce health-related costs in the workforce.

**Keywords:** Worker's health, Occupational Health, Sleep, Occupational risk, Actigraphy.

### Introduction

Actigraphy is a method used to infer sleep and wake patterns based on movement data collected through actigraphy. Its properties make it useful for collecting objective sleep data in large-scale research studies (Fekedulegn *et al.*, 2020). Actigraphy is more convenient, less invasive, and lower in cost compared to polysomnography, and it can be used continuously, 24 hours a day. It has been shown that the estimated agreement between polysomnography and actigraphy in sleep and circadian rhythm studies in the adult population ranges from 91% to 93% (Ancoli-Israel *et al.*, 2003; Fekedulegn *et al.*, 2020). The main motor activity parameter evaluated by actigraphy is the mean activity; the actigraph provides information about a patient's activity in an experimental environment or a natural setting over a prolonged and continuous period (De Crescenzo *et al.*, 2016).

The role of actigraphy may vary depending on the specific sleep disorder. In the case of insomnia disorder, actigraphy is more useful as a complement to sleep recordings or as an independent procedure in special cases where reliable self-reporting is not possible (Smith *et al.*, 2018). It can also be useful for documenting sleep deprivation, improving the interpretation of the Multiple Sleep Latency Test in adult and pediatric patients suspected of having central hypersomnolence disorders, and evaluating insufficient sleep syndrome (Smith *et al.*, 2018). Actigraphy can be useful for assessing total sleep time and sleep latency in patients with suspected and diagnosed insomnia disorder and provides a consistent measure of sleep latency compared to polysomnography (Smith *et al.*, 2018).

According to the Sleep Research Society (Oxford Academic), studies utilizing actigraphy for assessing and managing sleep disorders have led to the development of evidence-based guidelines for its clinical application. However, further research is necessary to refine its methodologies and enhance its clinical utility, allowing for

broader and more precise applications in sleep medicine (Morgenthaler *et al.*, 2007). Studies using simulated shift work data from individuals with both daytime and nighttime sleep have assessed the accuracy of various software methods in detecting sleep and wake periods. These findings highlight the application of actigraphy in worker populations (Gao *et al.*, 2022). In the field of occupational health, actigraphy can be of great importance for shift workers, who have been more frequently reported to experience poor sleep quality, insomnia, and daytime sleepiness; or for individuals in demanding jobs, which can have repercussions on their health, such as nurses, physicians, industrial and office workers (Güngördü *et al.*, 2023; Sadeghniaat-Haghighi *et al.*, 2020).

The aim of this review is to synthesize the available information on the use and importance of actigraphy in the field of occupational health.

## **Materials and Methods**

### ***Study design***

A literature review was conducted, including cohort, case-control, and cross-sectional studies, while excluding systematic reviews and other literature reviews. The methodology followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a rigorous and transparent selection process (Rethlefsen *et al.*, 2021).

### ***Search strategies***

The information search was conducted in English to access the broadest available data. Several libraries, repositories, and databases were utilized, including PubMed, Scopus, and Web of Science. The search terms employed were "actigraphy" and "work\* The study selection process comprised three exclusion stages. Initially, information published between 2019 and the January 2025 was sought, focusing on research articles from peer-reviewed journals and English papers to ensure scientific relevance. Duplicate records were eliminated. Subsequently, each article underwent analysis to exclude those not meeting the predefined inclusion criteria (Bustos *et al.*, 2019). Following this, a third exclusion phase was conducted to remove duplicate records. Finally, the full texts of the remaining articles were carefully reviewed.

### ***Inclusion criteria***

The primary inclusion criteria encompassed all workers assessed using actigraphy, with a specific focus on measurements conducted in real-world occupational settings.

### ***Data Synthesis***

All manuscripts meeting the inclusion criteria were thoroughly reviewed. Full-text versions of the selected studies were obtained to extract relevant data, which were systematically organized using a customized data collection table (Bustos *et al.*, 2021). Following this process, the extracted data were structured and integrated into comprehensive tables for analysis.

## **Results**

In accordance with the PRISMA Statement guidelines, a total of 2,781 records were identified through database searches. Search filters were then applied to refine the results based on criteria such as publication date, article type, source type, and language. The search strategy and filters were iteratively adjusted to ensure the extraction of relevant data from each database.

After removing duplicates and reviewing abstracts and full texts, 10 studies were selected for inclusion in the analysis. The results from these studies were organized into tables to outline their specific outcomes and

facilitate comparison across predefined categories for synthesis. A summary of the recompiled information is presented in Table 1.

**Table 1.** Summary of the studies.

| Authors, year                    | Country/region | Population                                                        | Target sample | Main findings                                                                                                                                                                               |
|----------------------------------|----------------|-------------------------------------------------------------------|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (Kunkels <i>et al.</i> , 2020)   | Netherlands    | athletes                                                          | -             | ACTman* automates actigraphy workflows, improving transparency, reproducibility, and scalability, addressing research bottlenecks.                                                          |
| (Baek <i>et al.</i> , 2020)      | South Korea    | shift work nurses                                                 | 94            | Strong agreement between sleep diary and actigraphy for total sleep time (ICC = 0.765-0.858) and sleep variability (ICC = 0.838), with diary overestimating total sleep time by 41-45 mins. |
| (Slavish <i>et al.</i> , 2020)   | United States  | nurses                                                            | 392           | IIV in sleep linked to higher IL-6 and IL-1 $\beta$ but not other inflammation biomarkers; shift work did not moderate associations.                                                        |
| (Cheng <i>et al.</i> , 2021)     | United States  | night shift workers                                               | 45            | Model predictions for DLMO showed good concordance with in-lab measurements (Lin's coefficient = 0.70), with a mean error of 2.88 hours.                                                    |
| (Lee <i>et al.</i> , 2021)       | United States  | full-time nurses.                                                 | 61            | Better sleep sufficiency led to increased mindful attention; mindful attention inversely related to sleepiness but not other sleep traits.                                                  |
| (Gerhardt <i>et al.</i> , 2020)  | Switzerland    | railway employees                                                 | 52            | Social stressors from supervisors linked to poorer sleep quality; higher time control at work improved sleep. Work redesign to reduce stress and increase control recommended.              |
| (Rodrigues <i>et al.</i> , 2023) | Spain          | -                                                                 | 55            | Workplace bullying linked to poorer sleep outcomes, with anxiety mediating the relationship between bullying and sleep disturbances.                                                        |
| (Devine <i>et al.</i> , 2020)    | United States  | United States Army Reserve Officers' Training Corps (ROTC) cadets | 286           | WORK-A** measures showed the best agreement with self-reported sleep times; larger discrepancies between Actiware and self-reports.                                                         |
| (Chabal <i>et al.</i> , 2024)    | United States  | Navy submariners                                                  | 58            | Submariners' sleep duration comparable to other Navy personnel; circadian alignment improved over time.                                                                                     |
| (Wang <i>et al.</i> , 2022)      | Canada         | naval personnel                                                   |               | Strong agreement between self-reports and actigraphy for sleep offset, but discrepancies for sleep onset latency and wake after sleep onset; better agreement for day workers.              |

\* **ACTman:** It is a tool that automatically preprocesses actinography input data into a uniform file format for further analysis (Kunkels *et al.*, 2020).

\*\* **WORK-A:** Is a set of actigraphy-derived measures adapted from commercial industry standards for the analysis of sleep patterns that are specific to active-duty soldiers in operational domains (Devine *et al.*, 2020)

## Discussion

### Workplace Stress and Sleep Quality

Gerhardt *et al.* (2020) highlighted the impact of workplace stress on sleep quality, particularly stress from supervisors. Their findings suggest that higher control over work schedules improves sleep outcomes, reinforcing the importance of reducing work-related stress and increasing employee autonomy to promote better sleep. Rodríguez-Muñoz *et al.* (2024) further emphasize this connection, showing that workplace bullying is associated with sleep disturbances, with anxiety acting as a mediating factor. These findings suggest that creating healthier work environments and addressing stressors could significantly improve sleep and overall well-being.

### Shift Work and Circadian Alignment

The impact of shift work on sleep quality is evident in studies such as those by Baek *et al.* (2020) and Wang *et al.* (2022), which report discrepancies between actigraphy and self-reported sleep data, particularly among night-shift workers. Workers on day shifts tend to have better sleep patterns and higher agreement between actigraphy and self-reports. Chabal *et al.* (2024) also found that submariners' sleep quality improved over time with better circadian alignment to their work schedule, highlighting the importance of adapting work shifts to the natural circadian rhythms of workers to minimize sleep disruption.

### Technological Advances in Sleep Monitoring

Kunkels *et al.* (2020) and Devine *et al.* (2020) underscore the importance of technological innovations like ACTman and WORK-A in improving the accuracy and efficiency of sleep monitoring in work settings. ACTman's automation of actigraphy processes addresses common bottlenecks in research, while WORK-A's superior alignment with self-reported sleep times offers a more reliable approach compared to traditional methods. These advancements are crucial in refining sleep studies, particularly in occupational settings where accurate data is necessary for improving worker health and performance.

## Conclusions

The findings from these studies underscore the critical role of workplace factors, such as stress and shift work, in influencing sleep quality. Technological tools for monitoring sleep have the potential to enhance accuracy and efficiency in research, providing valuable insights into how work-related conditions affect rest and overall health. Addressing work-related stressors and optimizing shift patterns in alignment with workers' natural rhythms could significantly improve sleep quality and employee well-being.

## Limitations

While the studies reviewed provide valuable insights into the relationship between work factors and sleep quality, several limitations must be considered. Many studies rely on self-reported data, which can introduce biases and inaccuracies, particularly when comparing subjective sleep diaries with objective measures like actigraphy. Additionally, the generalizability of some findings may be limited by specific populations, such as submariners or shift workers, whose unique work conditions may not reflect the broader workforce. The variability in methodologies and measurement tools across studies also presents challenges in drawing definitive conclusions, especially regarding the precision of sleep monitoring technologies in real-world settings. Another limitation includes the limited diversity of keywords available to search for information. Future research would benefit from larger, more diverse samples and the use of more standardized and advanced measurement techniques to better capture the complexities of sleep in occupational contexts.

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