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RISK-BASED PRIORITIZATION OF COMBINED OCCUPATIONAL HAZARDS IN REPAIR AND MECHANICAL ENTERPRISES: A FRAMEWORK FOR EXPOSURE–HEALTH ASSESSMENT

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Abstract

Repair and mechanical enterprises are characterized by heterogeneous technological processes that may expose workers simultaneously to physical, chemical, and ergonomic hazards. Conventional occupational hygiene approaches frequently assess individual hazards separately, which may underestimate the overall occupational burden when several exposures occur concurrently.

Objective: To develop a scientifically grounded methodological framework for quantitative prioritization of combined occupational hazards in repair and mechanical enterprises and to define an analytical pathway for evaluating their relationship with workers' health.

Materials and Methods: An analytical narrative review of contemporary occupational health literature was conducted with emphasis on multiple-exposure assessment, job-exposure matrices, occupational epidemiology, quantitative risk assessment, and prevention prioritization. PubMed-indexed studies, international occupational health evidence, and methodological recommendations from authoritative occupational safety institutions were considered. A multistage framework integrating exposure characterization, normalization against applicable occupational exposure limits, cumulative exposure profiling, interaction assessment, health-outcome modelling, and prevention prioritization was developed.

Results: The proposed framework consists of five sequential components: (1) identification and characterization of workplace hazards; (2) quantitative estimation of individual exposure burden; (3) construction of a job–exposure profile; (4)

statistical assessment of exposure–health relationships; and (5) prioritization of preventive interventions according to risk magnitude, preventability, and expected effectiveness. A normalized exposure ratio is proposed for individual hazards, while a weighted cumulative exposure score may be used for preliminary prioritization when methodological assumptions permit. For epidemiological analysis, multivariable logistic regression with interaction terms is recommended to distinguish independent and combined effects. The framework emphasizes that cumulative exposure should not be reduced to a simple arithmetic sum when hazards act through different biological pathways.

Conclusion: Quantitative assessment of combined occupational hazards should move beyond isolated measurements toward an integrated exposure–health–prevention model. The proposed framework can provide a methodological basis for occupational hygiene studies in repair and mechanical enterprises and may support the development of evidence-based, prioritized health-improvement interventions.

Keywords: occupational hygiene; combined exposure; multiple occupational hazards; repair and mechanical enterprises; quantitative risk assessment; job-exposure matrix; occupational health; exposure–health relationship; preventive measures.

Аннотация

Актуальность: Ремонтно-механические предприятия характеризуются разнообразными технологическими процессами, при которых работники могут одновременно подвергаться воздействию физических, химических и эргономических факторов. Традиционная оценка отдельных вредных факторов не всегда позволяет адекватно определить суммарную профессиональную нагрузку.

Цель: Разработать научно обоснованную методологическую модель количественной приоритизации комбинированных профессиональных

факторов риска на ремонтно-механических предприятиях и определить аналитический подход к изучению их взаимосвязи с состоянием здоровья работников.

Материалы и методы: Проведен аналитический нарративный обзор современной литературы по вопросам множественной профессиональной экспозиции, матриц «профессия–экспозиция», профессиональной эпидемиологии, количественной оценки риска и профилактики. На основе изученных источников предложена поэтапная модель, включающая характеристику экспозиции, ее нормирование относительно допустимых уровней, формирование профиля совокупной экспозиции, оценку связи с показателями здоровья и определение приоритетных профилактических мероприятий.

Результаты: Предлагаемая модель включает пять последовательных компонентов: идентификацию опасностей, количественную оценку индивидуальной экспозиции, построение профиля «профессия–экспозиция», статистический анализ связи экспозиции с показателями здоровья и приоритизацию профилактических мероприятий. Для отдельных факторов предлагается использовать нормированный коэффициент экспозиции, а для предварительного ранжирования — взвешенный показатель совокупной экспозиционной нагрузки. При эпидемиологическом анализе целесообразно применение многофакторной логистической регрессии с включением взаимодействий между факторами.

Заключение: Оценка комбинированных профессиональных факторов должна основываться не только на отдельных инструментальных измерениях, но и на интегрированной системе «экспозиция–здоровье–профилактика». Предлагаемая модель может быть использована в исследованиях условий труда работников ремонтно-механических предприятий.

Ключевые слова: гигиена труда; комбинированная экспозиция; профессиональные вредности; ремонтно-механические предприятия; количественная оценка риска; матрица «профессия–экспозиция»; здоровье работников; профилактика.

Annotatsiya

Dolzarbligi: Ta’mirlash-mexanika korxonalarida turli texnologik jarayonlar natijasida ishchilar bir vaqtning o‘zida fizik, kimyoviy va ergonomik zararli omillar ta’siriga duch kelishi mumkin. Alohida zararli omillarni mustaqil baholash ishchining umumiy kasbiy ekspozitsiya yuklamasini to‘liq aks ettirmasligi mumkin.

Maqsad: Ta’mirlash-mexanika korxonalarida kombinatsiyalangan kasbiy xavf omillarini miqdoriy ustuvorlashtirishning ilmiy asoslangan metodik modelini ishlab chiqish hamda ularning ishchilar salomatligi bilan bog‘liqligini baholashning analitik yondashuvlarini asoslash.

Materiallar va usullar: Ko‘p omilli kasbiy ekspozitsiya, “kasb–ekspozitsiya” matritsalari, kasbiy epidemiologiya, miqdoriy xavf baholash va profilaktika masalalariga bag‘ishlangan zamonaviy ilmiy adabiyotlarning analitik narrativ sharhi o‘tkazildi. Adabiyotlar asosida ishlab chiqarish xavflarini aniqlash, ekspozitsiyani miqdoriy baholash, kasbiy ekspozitsiya profilini shakllantirish, salomatlik ko‘rsatkichlari bilan statistik bog‘liqlikni aniqlash va profilaktik chora-tadbirlarni ustuvorlashtirishdan iborat bosqichma-bosqich model taklif etildi.

Natijalar: Taklif etilayotgan model besh asosiy bosqichni o‘z ichiga oladi: ishlab chiqarish xavflarini aniqlash; individual ekspozitsiya yuklamasini miqdoriy baholash; “kasb–ekspozitsiya” profilini shakllantirish; ekspozitsiyaning salomatlik ko‘rsatkichlari bilan bog‘liqligini statistik baholash; profilaktik chora-tadbirlarni ustuvorlashtirish. Alohida omillar uchun me’yorlashtirilgan ekspozitsiya koeffitsientidan, dastlabki ustuvorlashtirish uchun esa vaznlangan yig‘indi ekspozitsiya ko‘rsatkichidan foydalanish taklif qilinadi. Epidemiologik tahlilda

omillararo o‘zaro ta’sirni aniqlash uchun ko‘p omilli logistik regressiya va interaksiya hadlarini qo‘llash maqsadga muvofiq.

Xulosa: Kombinatsiyalangan kasbiy xavflarni baholash faqat alohida instrumental o‘lchovlar bilan cheklanmasdan, “ekspozitsiya–salomatlik–profilaktika” integratsiyalashgan tizimiga asoslanishi kerak. Taklif etilgan model ta’mirlash-mexanika korxonalarida mehnat gigiyenasi bo‘yicha tadqiqotlarni metodik jihatdan takomillashtirishga xizmat qilishi mumkin.

Kalit so‘zlar: mehnat gigiyenasi; kombinatsiyalangan ekspozitsiya; kasbiy xavf; ta’mirlash-mexanika korxonalari; miqdoriy xavf baholash; “kasb–ekspozitsiya” matritsasi; ishchilar salomatligi; profilaktika.

Introduction

Modern occupational hygiene increasingly recognizes that workers are rarely exposed to a single hazardous factor. Industrial workplaces may simultaneously contain physical agents such as noise and vibration, chemical contaminants including dust, welding fumes and solvents, and ergonomic or workload-related stressors. The resulting exposure profile is therefore multidimensional rather than represented by a single hazard.

This issue is particularly relevant to repair and mechanical enterprises, where technological processes commonly include machining, grinding, drilling, welding, metal cutting, assembly, equipment maintenance and surface treatment. Each process may generate a specific combination of occupational hazards. Moreover, workers may move between workstations during a shift, resulting in changing exposure intensity and duration.

Traditional occupational hygiene practice has often been organized around individual occupational exposure limits. This approach remains essential for identifying unacceptable exposures; however, it may be insufficient when several hazards occur simultaneously. A recent scoping review of multiple occupational exposures identified associations between combined exposures and nervous,

respiratory, musculoskeletal, auditory and other health outcomes, while emphasizing that prevention strategies addressing multiple exposures remain underdeveloped [1].

The problem is not simply that several exposure levels need to be added together. Different hazards may have different units, biological mechanisms, exposure metrics and health endpoints. For example, noise is quantified in decibels, vibration in acceleration-related metrics, airborne contaminants in mass concentration, and thermal stress through composite physiological or environmental indices. Direct arithmetic addition of such parameters is scientifically inappropriate.

The central methodological challenge is therefore to transform heterogeneous exposure measurements into a structured risk profile without losing information about the individual hazards or their possible interactions.

Evidence from occupational studies supports the relevance of this approach. A systematic review identified chemical, physical, personal and occupational factors that may modify the health effects of occupational noise, including vibration, heat, solvents, metals, workload, age and smoking [2]. More recent evidence from mechanical manufacturing workers has specifically examined combined dust and noise exposure in relation to blood pressure and electrocardiographic abnormalities [3]. A 2024 longitudinal and cross-sectional investigation also reported that combined noise and dust exposure was associated with increased risk of high-frequency hearing loss among occupationally exposed workers [4].

These findings indicate that occupational health research should increasingly move from a single-hazard paradigm toward an integrated exposure–health–prevention paradigm.

For repair and mechanical enterprises, such a transition is particularly important because the same worker may experience multiple hazards during a single shift and because exposure patterns may differ substantially according to occupation, department, technology, work experience and task duration.

The present article therefore focuses on a methodological problem: how to construct a quantitative and epidemiologically interpretable framework for combined occupational exposure assessment that can subsequently be applied to repair and mechanical enterprises.

Aim of the Study

The aim of this article was to develop a scientifically grounded methodological framework for:

quantitative characterization of multiple occupational exposures;

normalization and comparison of heterogeneous exposure indicators;

construction of occupation-specific exposure profiles;

statistical evaluation of exposure–health relationships;

identification of potentially interactive effects between occupational hazards; and

prioritization of preventive interventions according to measurable occupational risk.

Materials and Methods

The article represents an analytical methodological review rather than an empirical epidemiological study. Therefore, no original measurements, clinical observations or numerical health outcomes from repair and mechanical enterprises are presented as study results.

The analytical framework was developed through examination of peer-reviewed occupational health literature, systematic reviews and methodological publications concerning multiple occupational exposures, job-exposure matrices, quantitative risk assessment and occupational prevention.

Particular attention was given to evidence concerning:

combined occupational exposures;

manufacturing and mechanical workplaces;

physical and chemical co-exposures;

exposure–health associations;

quantitative exposure metrics;

job-exposure matrices;

multivariable epidemiological models; and

hierarchy-based prevention.

Conceptual basis of the proposed framework

The proposed framework is based on five analytical stages:

Stage 1 — Hazard identification

All relevant physical, chemical and ergonomic factors are identified according to technological processes and occupational tasks.

Stage 2 — Quantitative exposure assessment

Each exposure is measured or estimated using an appropriate exposure metric and compared with the applicable occupational reference value.

Stage 3 — Exposure normalization and profiling

Heterogeneous measurements are transformed into dimensionless indicators to facilitate comparison while retaining the original exposure data.

Stage 4 — Exposure–health modelling

Individual and combined exposures are related to predefined health outcomes using appropriate statistical models.

Stage 5 — Prevention prioritization

Interventions are ranked according to the magnitude of exposure, health relevance, feasibility of control and expected effectiveness.

Results and Discussion

A worker in a repair-mechanical enterprise may perform several operations during one working day. A metalworker, for example, may spend part of the shift cutting or grinding metal, another period welding, and additional time operating or maintaining machinery.

Consequently, the exposure profile is dynamic.

The same worker may receive:

noise exposure from mechanical equipment;

hand-transmitted vibration from powered tools;

inhalation exposure to metal dust or welding fumes;

thermal stress under unfavorable microclimatic conditions;

physical workload associated with manual handling; and

intermittent exposure to solvents or other chemical agents.

A conventional assessment that reports each hazard independently may correctly identify whether an individual exposure exceeds its reference limit but may fail to describe the worker's overall exposure pattern.

The problem becomes particularly important when exposures influence the same biological system.

Thus, exposure assessment should preserve the individual hazards while simultaneously describing their combined occurrence.

Occupational group	Noise	Vibration	Dust/aerosols	Chemical exposure	Thermal stress	Physical workload
Machinists	+++	++	++	+	+	++
Welders	++	+	+++	+++	++	++
Grinders	+++	+++	+++	+	+	++
Maintenance workers	++	++	++	++	+	+++
Assemblers	++	+	+	+	+	++

The symbols in such a matrix should not be interpreted as empirical results unless they are derived from actual measurements. They represent a proposed structure for organizing future measurements.

The selection of health outcomes should correspond to the biological plausibility of the exposure.

For example:

Exposure	Potentially relevant health outcome
Noise	hearing impairment, blood pressure, cardiovascular outcomes

Exposure	Potentially relevant health outcome
Vibration	musculoskeletal, neurological and vascular symptoms
Dust/aerosols	respiratory symptoms and pulmonary function
Welding fumes	respiratory and systemic outcomes
Heat stress	cardiovascular and physiological strain
Physical workload	musculoskeletal disorders and fatigue

The purpose is not to assume that every exposure causes every listed outcome. Instead, exposure–outcome pairs should be defined a priori based on scientific evidence

The methodological novelty of the proposed framework lies not in introducing a new measurement device or replacing existing occupational exposure limits, but in integrating several established approaches into a single analytical pathway.

Conclusion

Combined occupational exposure represents a major methodological challenge for contemporary occupational hygiene, particularly in industrial workplaces where workers encounter several physical, chemical and ergonomic hazards during the same working period. For repair and mechanical enterprises, assessment based exclusively on individual hazards may provide an incomplete picture of occupational burden. A more informative approach should integrate hazard identification, quantitative exposure measurement, exposure normalization, occupation-specific exposure profiling, health assessment, statistical interaction analysis and preventive prioritization. The methodological framework proposed in this article provides five interconnected stages: exposure characterization, quantitative normalization, job–exposure profiling, exposure–health modelling and prevention prioritization.

Ultimately, the most scientifically valuable occupational hygiene model is not one that merely identifies whether individual exposure limits are exceeded, but one that explains which combination of exposures creates the greatest preventable health

burden, which workers are most affected, and which interventions are likely to produce the greatest health benefit.

References

1. Barbey C, Bonvallot N, Clerc F. Health outcomes related to multiple exposures in occupational settings: a review. *Safety and Health at Work*. 2024;15(4):382–395. doi:10.1016/j.shaw.2024.10.004.
2. Golmohammadi R, Darvishi E. The combined effects of occupational exposure to noise and other risk factors: a systematic review. *Noise and Health*. 2019;21(101):125–141. doi:10.4103/nah.NAH_4_18.
3. Hai R, Gao XP, Xu LJ, Liang XQ, Liu MT, Ning L. Effects of combined exposure to dust and noise on blood pressure and electrocardiogram of mechanical manufacturing workers. *Chinese Journal of Industrial Hygiene and Occupational Diseases*. 2025;43(4):275–280. doi:10.3760/cma.j.cn121094-20240120-00030.
4. Zhou B, Zhang J. Occupational epidemiological characteristics of noise-induced hearing loss and the impact of combined exposure to noise and dust on workers' hearing: a retrospective study. *Frontiers in Public Health*. 2024;12:1488065. doi:10.3389/fpubh.2024.1488065.
5. Teixeira LR, Pega F, Dzhambov AM, et al. The effect of occupational exposure to noise on ischaemic heart disease, stroke and hypertension: a systematic review and meta-analysis from the WHO/ILO Joint Estimates of the Work-Related Burden of Disease and Injury. *Environment International*. 2021;154:106387. doi:10.1016/j.envint.2021.106387.
6. De Roos AJ, Teschke K. Job exposure matrices in industry. *International Journal of Epidemiology*. 1993;22(Suppl 2):S10–S15. doi:10.1093/ije/22.supplement_2.s10.

7. Huntley CC, Bhomra P, Walters GI. Job exposure matrices for occupational respiratory disease: a narrative review. *Occupational Medicine*. 2023;73(5):263–267. doi:10.1093/occmed/kqad064.
8. National Institute for Occupational Safety and Health. Hierarchy of Controls. Centers for Disease Control and Prevention; 2024.
9. Schulte PA, Pandalai S, Wulsin V, Chun H. Interaction of occupational and personal risk factors in the development of chronic disease. *American Journal of Public Health*. 2012;102(3):434–448.
10. Sexton K. Cumulative risk assessment: an overview of methodological approaches for evaluating combined health effects from exposure to multiple environmental stressors. *International Journal of Environmental Research and Public Health*. 2012;9(2):370–390. doi:10.3390/ijerph9020370.
11. Blondin B, et al. Cumulative risks from stressor exposures and personal risk factors in the workplace: examples from a scoping review. *Journal of Occupational and Environmental Medicine*. 2021.
12. Teixeira LR, et al. The prevalence of occupational exposure to noise: a systematic review and meta-analysis from the WHO/ILO Joint Estimates of the Work-related Burden of Disease and Injury. *Environment International*. 2021;154:106380.