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LITERATURE REVIEW

NOISE EXPOSURE AND HEARING IMPAIRMENT AMONG MANUFACTURING INDUSTRY WORKERS: A SYSTEMATIC LITERATURE REVIEW

(PAPARAN KEBISINGAN DAN GANGGUAN PENDENGARAN DI KALANGAN PEKERJA INDUSTRI MANUFAKTUR: SYSTEMATIC LITERATURE REVIEW)

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ABSTRACT

Noise exposure is a major occupational risk factor contributing to Noise-Induced Hearing Loss (NIHL), particularly in the manufacturing sector where noise levels are typically high. This study aims to examine the association between occupational noise exposure and hearing impairment through a Systematic Literature Review (SLR) conducted using the PRISMA framework. Literature searches were performed across PubMed, ScienceDirect, SpringerLink, Scopus, Google Scholar, and Garuda using the keywords “noise exposure,” “industrial worker,” “manufacturing industry,” and “hearing loss,” covering publications from 2010 to 2025. Of the 50 articles identified, 25 met the inclusion criteria, which are published between 2010-2025 and full-text availability. The synthesized findings indicate that noise exposure exceeding 85 dBA consistently increases the risk of NIHL, particularly among workers with more than five years of employment. The use of hearing protection devices and the implementation of a Hearing Conservation Program (HCP) were shown to reduce the risk of hearing loss by approximately 30–40%. These results highlight the critical role of noise control within occupational health and safety management systems, especially in alignment with ISO 45001 requirements.

Keywords: hearing loss, manufacturing industry, noise, occupational health and safety

ABSTRAK

Paparan kebisingan merupakan faktor risiko pekerjaan utama yang berkontribusi terhadap Noise-Induced Hearing Loss (NIHL), khususnya di sektor manufaktur dengan tingkat kebisingan tinggi. Studi ini bertujuan untuk menganalisis hubungan antara paparan kebisingan kerja dan gangguan pendengaran melalui Systemativ Literatur Review (SLR) yang dilakukan menggunakan kerangka kerja PRISMA. Pencarian literatur dilakukan di PubMed, *ScienceDirect, SpringerLink, Scopus, Google Scholar, dan Garuda menggunakan kata kunci "paparan kebisingan," "pekerja industri," "industri manufaktur," dan "gangguan pendengaran," yang mencakup publikasi dari tahun 2010 hingga 2025. Dari 50 artikel yang diidentifikasi, 25 memenuhi kriteria inklusi, yaitu diterbitkan antara tahun 2010-2025 dan tersedia teks lengkapnya. Temuan yang disintesis menunjukkan bahwa paparan kebisingan yang melebihi 85 dBA secara konsisten meningkatkan risiko NIHL, khususnya di antara pekerja dengan masa kerja lebih dari lima tahun. Penggunaan alat pelindung pendengaran dan implementasi Program Konservasi Pendengaran/Hearing Conservation Program (HCP) terbukti mengurangi risiko gangguan pendengaran sekitar 30–40%. Hasil ini membuktikan peran penting pengendalian kebisingan dalam sistem manajemen kesehatan dan keselamatan kerja, terutama dalam kaitannya dengan persyaratan ISO 45001.*

Kata kunci: gangguan pendengaran, industri manufaktur, kebisingan, kesehatan dan keselamatan kerja

INTRODUCTION

Noise-Induced Hearing Loss (NIHL) remains one of the most prevalent occupational diseases worldwide, particularly in the manufacturing sector where continuous high-intensity noise is common. Prolonged exposure to hazardous noise can cause irreversible damage to the cochlear hair cells, resulting in permanent threshold shifts, communication difficulties, reduced job performance, and diminished quality of life. Globally, the World Health Organization (2021) estimates that approximately 16% of hearing loss cases are attributable to occupational noise exposure, highlighting its substantial public health burden.[1] In addition to intensity and duration, several modifying factors increase NIHL susceptibility, including individual age, genetic predisposition, exposure to ototoxic chemicals (e.g., toluene, styrene, and heavy metals), and simultaneous exposure to vibration. Evidence shows that combined exposure to noise and ototoxic substances can accelerate cochlear cell degeneration and double the risk of hearing loss. Furthermore, inadequate use of hearing protection devices (HPDs), poor compliance, and insufficient monitoring programs contribute significantly to NIHL prevalence in industrial settings.[2]

Research on occupational noise exposure is of high importance because noise is recognized as one of most consistently reported, and most preventable risk factors for hearing impairment, particularly noise-induced hearing loss (NIHL). Exposure to noise levels exceeding established threshold limits can lead to cumulative and irreversible damage to the sensory hair cells of the cochlea, resulting in a progressive decline in auditory function and a subsequent reduction in workers' quality of life.[3]International occupational health guidelines emphasize the importance of comprehensive noise management. NIOSH recommends limiting exposure to 85 dBA for 8 hours and reducing permissible duration with increasing intensity. Similarly, ISO 45001 and ILO standards advocate implementation of a structured Hearing Conservation Program (HCP), including engineering controls, administrative controls, regular audiometric testing, worker training, and effective use of HPDs.[4] Given the persistent burden of NIHL and its preventability, this review aims to synthesize empirical evidence on the association between occupational noise exposure and hearing impairment among manufacturing workers. The findings are expected to strengthen the scientific basis for improving occupational health and safety (OHS) policies, informing risk management strategies, and optimizing hearing conservation programs within industrial environments.[5]

Manufacturing industries often present noise levels exceeding recommended limits. While Indonesia sets a permissible exposure limit (PEL) of 85 dBA for an 8-hour workday, measurements in sectors such as textile, automotive, metal processing, and heavy machinery frequently report noise levels reaching 95–105 dBA.[6] Similar trends have been documented globally; studies from NIOSH and OSHA indicate that nearly 22 million workers in the United States alone are exposed to hazardous noise each year.[7] These findings underscore manufacturing environments as high-risk settings for NIHL.[5]

MATERIALS AND METHODS

This study employed a Systematic Literature Review (SLR) approach following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The method was structured to ensure a transparent, reproducible, and comprehensive synthesis of evidence regarding occupational noise exposure and Noise-Induced Hearing Loss (NIHL) among manufacturing workers.

The stages in this research can be explained as follows:

The research questions were formulated using the PICOC framework to define the scope and focus of the review. PICOC Components as follows: Population (P): Manufacturing industry workers exposed to workplace noise; Intervention: Noise exposure ≥85 dBA; Comparison (C): Workers unexposed or exposed below the threshold limit; Outcomes (O):[7] NIHL, threshold shift, tinnitus Context (C): Global manufacturing industry settings Research Questions (RQs). RQ1: How occupational noise exposure associated with hearing loss among manufacturing workers? RQ2: What factors influence the effect of noise exposure on hearing outcomes? RQ3: How effective are noise control programs implemented in manufacturing industries?

A comprehensive literature search was conducted across major scientific databases, including PubMed, ScienceDirect, SpringerLink, Scopus, Google Scholar, and the Indonesian national portal Garuda. Grey literature was retrieved from Neliti and WHO technical reports. Search Keywords, such as: ("Noise-Induced Hearing Loss" OR "occupational noise") AND ("manufacturing" OR "industry") AND ("workers" OR "hearing impairment"). Inclusion Criteria in this study are 1) empirical studies examining noise exposure and hearing loss in manufacturing workers; 2) articles published between 2010–2025; 3) English or Indonesian language publications; and 4) full-text availability. While the exclusion criteria are review articles, conceptual papers, or studies unrelated to manufacturing and also as studies without empirical data.

The selection process followed four PRISMA stages: identification, screening, eligibility assessment, and inclusion. A total of 50 studies were initially identified. After removal of duplicates and title–abstract screening, 32 studies remained. After applying eligibility criteria, 25 studies were included in the final synthesis.

The methodological quality of each included study was evaluated based on the Joanna Briggs Institute (JBI) appraisal tools, assessing: 1) Clarity of objectives; 2) Appropriateness of study design, 3) Validity of noise measurement and audiometric outcomes; 4) Relevance to manufacturing settings and occupational safety context. Data were extracted systematically, covering: author, publication year, country, study design, sample size, noise exposure levels, key outcomes (NIHL, threshold shift, tinnitus), and major findings. Narrative-descriptive synthesis was performed due to heterogeneity in research designs and exposure assessment methods. Patterns were identified regarding noise intensity, exposure duration, use of hearing protection, and the effectiveness of HCPs. Prisma Diagram shown at Fig 1.

A total of 25 studies met the inclusion criteria and were analyzed as part of this systematic review. Most of the included studies employed a cross-sectional design, with research locations spanning Indonesia, India, South Korea, and other countries with developing manufacturing sectors. The number of participants in each study ranged from 50 to more than 1,000 workers.

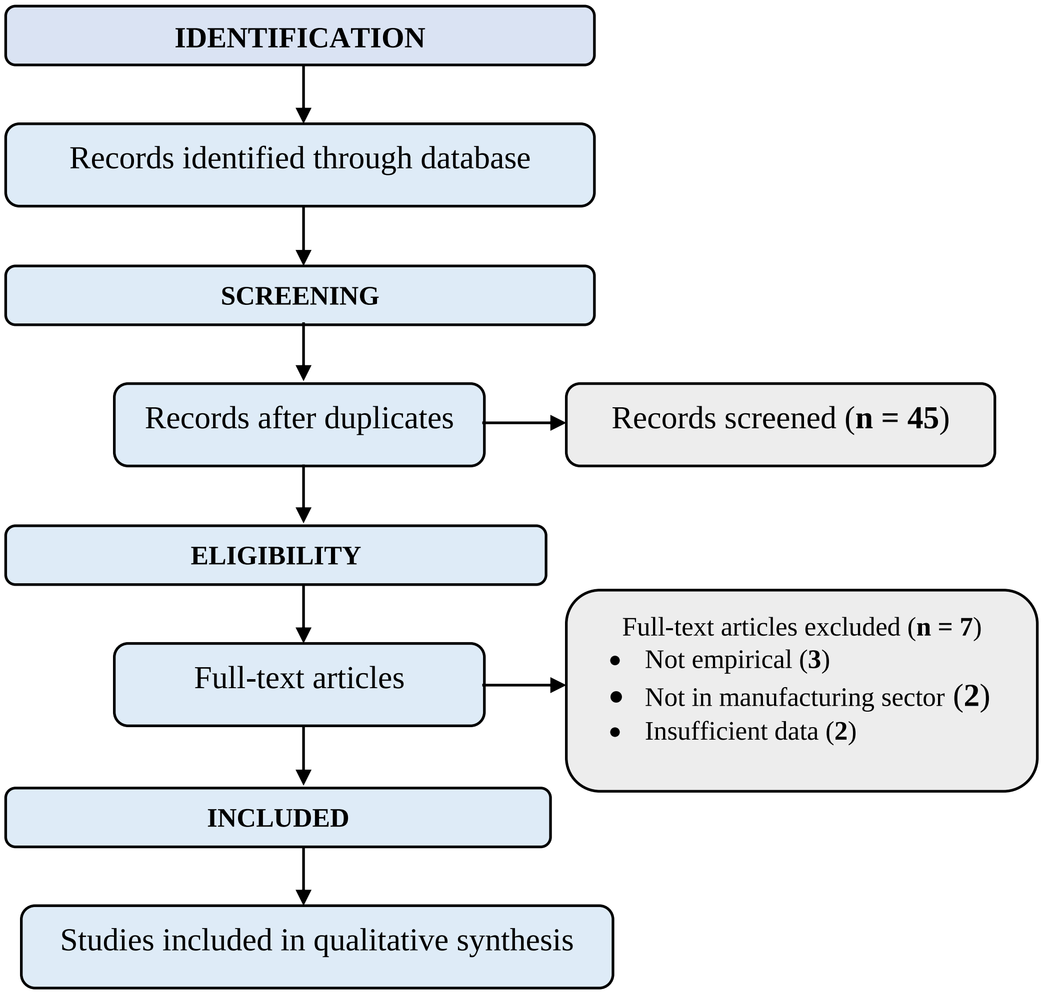

Figure 1 PRISMA Flowchart for systematic literature review.

RESULTS AND DISCUSSION

The majority of studies measured noise levels in production areas, reporting values between 85 and 105 dB(A), particularly in the textile, automotive, metal, and cement industries.

Nearly all studies reported that noise levels exceeding 85 dB(A) were consistently associated with an increased risk of hearing impairment. The highest exposure levels were observed in the metal industry (up to 105 dB(A)) and the textile industry (92–100 dB(A)). Long-term and chronic exposure was identified as a major contributor to the decline in hearing function.

The synthesis of findings indicates that: Workers with ≥5 years of service had a 2–4 times higher risk of developing NIHL compared to newly employed workers. Noise exposure above 85 dB(A) increased the prevalence of NIHL to 40–52% in several industrial sectors. The most commonly reported outcomes included elevated hearing thresholds, tinnitus, and high-frequency hearing loss.

Several factors were identified as strengthening the association between noise exposure and hearing impairment, including: age, duration of employment, non-compliance with hearing protection, type of job or production process, and ineffective noise control measures. Formers studies emphasized that proper and consistent use of earplugs or earmuffs significantly reduced the risk of NIHL.[8]

Hearing impairment is a multifactorial condition that is influenced not only by noise exposure but also by various confounding variables that may affect auditory function independently or interact with noise exposure. The presence of these confounding factors may obscure or amplify the observed association between noise and hearing impairment if they are not adequately addressed in the study design and interpretation of findings. Exposure to ototoxic chemicals, such as organic solvents (e.g., toluene, styrene, and xylene), heavy metals, and certain pesticides has been associated with damage to cochlear hair cells and auditory neural pathways. When chemical exposure occurs concurrently with noise exposure, synergistic effects may arise, further exacerbating hearing impairment. This interaction highlights chemical exposure as an important confounding variable in studies of occupational hearing loss.[9]

Therefore, a history of ear disease, diabetes mellitus, and exposure to ototoxic chemicals should be considered potential confounders due to their strong associations with hearing impairment. Accounting for these factors is essential to maintain the internal validity of the study and to ensure an accurate interpretation of the relationship between noise exposure and hearing impairment.

Across the reviewed literature: Implementation of a Hearing Conservation Program (HCP) was shown to reduce NIHL prevalence by 30–40% (Sutopo et al., 2020). Correct and consistent use of hearing protection devices was found to be most effective in areas with noise levels above 95 dB(A). Annual audiometric examinations contributed to the early detection of hearing threshold shifts.

Table 1 shows that metal industry exhibited the highest risk of NIHL (52%). Average noise levels across all sectors ranged from 88 to 105 dB(A), indicating that most production areas operated well above the permissible exposure limits and pose a substantial risk for occupational hearing loss.[10]

The findings of this systematic review provide consistent evidence that occupational noise exposure remains a major determinant of Noise-Induced Hearing Loss (NIHL) among workers in the manufacturing sector.

Table 1 Average noise level and NIHL Risk among variety sectors

Sector	Average Noise Level (dB[A])	NIHL Risk (%)
Textile	92–100	45
Automotive	88–96	38
Metal	94–105	52
Cement	90–98	41

The results reaffirm the global concerns highlighted by the World Health Organization (2021), which estimates that approximately 16% of disabling hearing loss worldwide is attributable to occupational noise exposure. Across the 25 included studies, noise levels ranged from 85 to 105 dB(A), exceeding the recommended exposure limits set by NIOSH (85 dB(A) with a 3 dB exchange rate) and OSHA (90 dB(A) with a 5 dB exchange rate). These findings emphasize the substantial risk posed by high-intensity and prolonged noise exposure.

The majority of studies reported significant threshold shifts at high frequencies (3–6 kHz), a classic hallmark of NIHL. This pattern aligns with evidence that the cumulative degeneration of cochlear hair cells following chronic acoustic overstimulation.[11] The increased risk observed among workers with ≥5 years of employment supports the dose–response relationship widely recognized in epidemiological studies, including a meta-analysis, which reported a 1.8–3.5-fold increase in NIHL risk among manufacturing workers.[12]

The prevalence of NIHL reported in the reviewed studies (25–55%) is comparable to findings from industrial settings in India, Turkey, China, and Vietnam, suggesting that the issue transcends geographical and economic differences. High-noise sectors such as textiles, automotive production, metalworking, and cement manufacturing consistently demonstrated elevated noise levels and a higher burden of NIHL. Similar patterns reported in Indonesian studies indicate that industrial noise exposure in emerging economies poses comparable risks to workers globally.[14]

Evidence from the European Agency for Safety and Health at Work (EU-OSHA, 2019) shows accelerated hearing decline among older workers due to reduced cochlear resilience.[15]

Longitudinal findings indicate that smokers have a 1.6-fold increased risk of NIHL, attributed to nicotine-induced vasoconstriction affecting cochlear microcirculation.[16] Smoking has been suggested as a potential contributor to hearing loss through several biological mechanisms. Nicotine and carbon monoxide in cigarette smoke may induce vasoconstriction and reduce oxygen-carrying capacity, thereby impairing oxygen and nutrient delivery to the cochlea. In addition, toxic substances in tobacco smoke can increase oxidative stress and damage sensory hair cells as well as auditory neural pathways. These processes may accelerate auditory deterioration, particularly among individuals exposed to other risk factors.[17] In the present study, however, smoking was not significantly associated with hearing loss. This finding suggests that the effect of smoking on auditory function may not occur in isolation and could be influenced by factors such as smoking intensity and duration, age, underlying health conditions, and the presence of more dominant risk exposures. The findings of this study are consistent with several previous investigations reporting that the association between smoking and hearing loss becomes attenuated or non-significant after adjustment for occupational noise exposure. These studies indicate that noise exposure may play a more prominent role in the development of hearing loss, potentially masking the independent effect of smoking.

Conversely, other studies have demonstrated a significant association between smoking and an increased risk of hearing loss, particularly among heavy smokers or individuals with long-term noise exposure. Some evidence also suggests a synergistic effect, whereby combined exposure to smoking and noise results in a greater risk of hearing loss than either exposure alone. Variations in study design, population characteristics, exposure assessment, and control of confounding factors may account for these inconsistent findings.[18]

NIOSH highlights synergistic effects between noise and solvents (e.g., toluene, styrene), carbon monoxide, or heavy metals, which exacerbate cochlear damage.[7] Recreational noise, particularly from loud music or motorcycling, has been identified as an additional burden.[19]

Poor room acoustics, reflective surfaces, and inadequate ventilation can amplify effective noise exposure, as noted in ISO 11690-1 guidelines. These determinants help explain variations in NIHL prevalence across industries and underscore the multifactorial nature of occupational hearing loss.[20]

The review also highlights the significant role of Hearing Conservation Programs (HCPs) in mitigating NIHL. Comprehensive HCPs including engineering controls, administrative controls, hearing protection devices (HPDs), and periodic audiometric monitoring were shown to reduce NIHL prevalence by up to 30–40%.[21]

Engineering Controls including machine enclosures, vibration dampening, and regular equipment maintenance can reduce noise levels by 5–10 dB(A). However, their implementation remains limited in many manufacturing settings due to cost and technical constraints.

Work rotation and exposure time reduction are moderately effective but do not eliminate high-intensity exposure. HPDs demonstrated high potential effectiveness, but real-world protection often falls short of the labeled Noise Reduction Rating (NRR). Field performance is typically only 50% of laboratory-rated values in the absence of training and fit-testing. Programs emphasizing individualized fit-testing significantly improved protective outcomes.[22]

Annual audiometric testing enables early detection of standard threshold shifts (STS), which is essential in preventing progressive NIHL. However, several included studies noted irregular testing schedules and inadequate interpretation of audiograms.[7]

The results highlight several critical recommendations: at the organizational level: Integration of HCP into ISO 45001 frameworks, routine noise mapping, mandatory HPD fit-testing, conduct of baseline audiometry for all new workers, and strengthening accountability for PPE compliance. In the regulatory level: Harmonization of national noise exposure limits with international standards (e.g., NIOSH 3 dB exchange rate), improved enforcement of workplace inspections, and incentives for implementing engineering controls. At the worker level: Promotion of hearing health literacy, training on proper HPD use, and education regarding non-occupational noise risks.[23]

The review has several limitations, including the predominance of cross-sectional designs, variability in noise measurement methodologies, underreporting of confounding exposures and heterogeneity in NIHL diagnostic criteria. Nonetheless, the consistency of findings across multiple settings strengthens the overall validity of the conclusions.

Further research is needed to support long-term prevention strategies, including: longitudinal cohort studies, evaluations of engineering control effectiveness, predictive NIHL modeling using machine learning, standardized noise measurement, audiometry protocols, and investigations into combined exposure risks.

CONCLUSION

This systematic review demonstrates strong and consistent evidence that occupational noise exposure exceeding 85 dB(A) significantly increases the risk of Noise-Induced Hearing Loss (NIHL) among manufacturing workers. The findings highlight a clear dose–response relationship influenced by exposure duration, age, work processes, and compliance with hearing protection. Effective Hearing Conservation Programs encompassing engineering controls, administrative measures, annual audiometric surveillance, and proper hearing protection use remain the most reliable approach to mitigating NIHL risk.

The review also reveals substantial gaps in long-term cohort data and variability in measurement methods across studies. Future research should prioritize longitudinal designs, evaluation of engineering controls, and development of predictive NIHL models to enhance early detection and prevention. Strengthening regulatory enforcement and integrating hearing conservation into broader OHS management systems, such as ISO 45001, will be essential to protecting workers in high-risk industrial environments.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to the research, authorship, or publication of this manuscript.

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