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Screening for Noise-Induced Hearing Loss among Palm Oil Mill Workers in Peninsular Malaysia: A Comparison across Noise Exposure Levels

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Abstract: Background: Palm oil mill workers in Malaysia are exposed to hazardous levels of noise in the workplace, and thus are at risk of developing noise-induced hearing loss (NIHL). In 2019, Malaysia introduced a new noise regulation, which reduced the level of permissible noise exposure. Objectives: This study aims to determine the prevalence of NIHL among palm oil mill workers based on screening data and assess the effects of different noise exposure levels on NIHL. Methods: A cross-sectional study was conducted by analyzing data from noise risk assessment reports of selected mills and screening audiometric data from workers. NIHL was defined as bilateral high-frequency hearing loss. Results: The overall NIHL prevalence was 50.8%. Noise exposure level and age were significant predictors of NIHL among the workers. The risk of developing NIHL was high even for workers who were not categorized in the high-risk group. Conclusions: In view of the findings, a precautionary approach is needed when evaluating the risk of NIHL in the study population. Vulnerable groups of workers must be protected from occupational noise hazards through the implementation of effective hearing conservation programs in the workplace.

Keywords: noise-induced hearing loss; noise legislation; palm oil; Malaysia; exposure level

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1. Introduction

Occupational noise-induced hearing loss (NIHL) has long been identified as a major occupational health issue. Chronic exposure to noise levels exceeding 85 dBA is a known risk factor for developing NIHL [1,2]. Acute NIHL can also occur during occupational exposure to loud impulsive noise, for example, in soldiers when a gun is fired [3]. The impact of NIHL is not only limited to hearing disability, but it can also lead to social isolation, loss of productivity, mental health issues, as well as an increased risk of injuries [1].

The global prevalence of disabling hearing loss was estimated to be 6.12% in 2018 and is projected to grow to 9.6% by 2050, with noise exposure being one of the major contributors to this problem [4]. Rapid industrialization, especially in Asian countries, has caused a surge in the population of workers exposed to hazardous levels of noise at the workplace [5]. Malaysia as a developing country has embraced industrialized agriculture on a massive scale, enabling it to become one of the biggest producers of palm oil in the world [6]. In 2019, the total oil palm plantation area in the country was 5.9 million hectares, producing almost 20 million tonnes of crude palm oil. Currently, there are more than 450 palm oil mills in operation throughout Malaysia [7].

The production of crude palm oil begins with the harvesting and transporting of fresh fruit bunches to mills, which are usually located in the vicinity of the plantation areas. The fruit bunches are sterilized using steam before undergoing the threshing process to strip the fruitlets from the bunches. Next, the fruitlets are transported through the digester and the press machine to extract crude palm oil. The pressed digested fruit are further processed to produce fibers, palm shells and kernels [8]. The entire operation of palm oil mills has been documented to generate hazardous levels of noise due to the processes and machineries involved, exposing the workers to noise levels exceeding 85 dBA [9–12].

Since 1989, employers in Malaysia have been mandated by law to identify workers who are exposed to noise exceeding the action level of 85 dBA, and to carry out necessary interventions to protect their hearing. The permissible exposure limit (PEL) was defined as an equivalent continuous sound pressure level of 90 dBA, a maximum noise level of 115 dBA, or a peak sound pressure level of 140 dB [13]. In 2019, a new regulation on noise exposure was enforced. The term "excessive noise" was introduced, defined as a daily noise exposure level exceeding 82 dBA, daily personal dose exceeding 50%, maximum sound pressure level exceeding 115 dBA, or peak sound pressure level exceeding 140 dBC. The noise exposure limit (NEL) is similar to the previous PEL, but with a reduced daily exposure level of 85 dBA. Workers exposed to noise exceeding the NEL are required to undergo annual audiometric tests. The new regulation also made it mandatory for employers to demarcate areas with noise exceeding NEL as "Hearing Protection Zones" [14].

Numerous studies have described age and work duration as significant predictors of NIHL [15–20]. NIHL is also associated with other factors, including leisure time exposure, chemical exposure, vibration exposure, cigarette smoking, education level, hypertension, and the use of hearing protection devices [16,21–24].

Taking into account the high level of noise at the mills and the implementation of the new regulation, our study seeks to estimate the prevalence of NIHL among palm oil mill workers using data from screening audiometric tests and to assess the significance of different noise exposure levels as a predictor of NIHL.

2. Materials and Methods

2.1. Study Population and Sampling Method

This cross-sectional study was conducted in the eastern region of Peninsular Malaysia from June 2019 until June 2020. The study duration coincides with the transition period from the previous 1989 noise regulation to the newly enforced 2019 noise regulation. Using a random number generator, ten mills were selected from a list of licensed palm oil mills in the region and received an invitation to participate in the study. Each mill employed about 50 to 100 workers, made up almost entirely of local residents.

Sample size was calculated based on a small-scale study involving workers in a palm oil mill in the neighboring country of Indonesia. The study reported that 35% of workers were detected to have NIHL, according to their audiogram results [12]. With a 5% margin of error at 95% confidence level, the estimate sample size was 350. Anticipating a 20% incomplete data percentage, a total of 420 workers was needed for this study. Taking into consideration the need to assess individual workers according to their respective noise exposure levels, sampling was performed by randomly selecting palm oil mills and including all the workers from those mills.

The inclusion criteria were employees aged 18 and above with a work duration of at least 6 months who had undergone annual audiometric test within one year from the date of data collection. We excluded those who had been diagnosed with any hearing-related medical condition or sustained injury that would have directly affected his or her hearing condition.

2.2. Study Subjects

Nine mills agreed to participate, with a total of 522 workers. Although annual audiometric tests are only mandatory for workers exposed to noise exceeding the noise exposure limit, all of the workers from these nine mills regardless of noise exposure level underwent screening audiometric tests in either 2019 or 2020. A total of 28 workers were excluded: 8 due to hearing-related medical conditions, and 20 due to work duration of less than 6 months. To ensure confidentiality, audiometric data were deidentified and each worker was assigned a combination of letters and numbers as identifiers for data analysis purposes.

2.3. Noise Assessment Report (NRA)

Due to the excessive noise generated during operation, palm oil mill employers are required to appoint a licensed noise risk assessor to conduct a yearly noise risk assessment. The equipment used in this assessment, such as sound level meters and noise dosimeters, was to be calibrated within one year of the assessment. Sound level meters are required to comply to the requirement for IEC 61672-1, class 1 or class 2 instrumentation. Noise dosimeters including a microphone and the associated cable are required to comply to the requirement specified in IEC 61252. The noise dosimeter setup was as follows: criterion level of 85 dBA, threshold level of 80 dBA, exchange rate of 3 dB, time constant set at "slow", and peak level of 140 dBC. Sound level calibrators are required to comply with the requirements specified in IEC 60942, class 1. The NRA include the identification of similar exposure groups, noise area mapping, and personal noise exposure evaluations for relevant workers according to their workstations. Workers are provided with hearing protection devices and are expected to wear them whenever they enter the designated hearing protection zones [25].

Based on the NRA, we categorized the workers into three exposure groups: low, moderate and high exposure. Workers stationed in office buildings away from machinery noises were put into the low exposure group. The moderate exposure group comprised workers who were exposed to excessive noise that did not exceed the NEL. Workers exposed to noise exceeding the NEL were categorized into the high exposure group. Excessive noise was defined as "daily noise exposure level exceeding 82 dBA or daily personal noise dose exceeding fifty percent, or maximum sound pressure level exceeding 115 dBA at any time, or peak sound pressure level exceeding 140 dBC". Noise exposure limit (NEL) was defined as "daily noise exposure level exceeding 85 dBA or daily personal noise dose exceeding one hundred percent, or maximum sound pressure level exceeding 115 dBA at any time, or peak sound pressure level exceeding 140 dBC" [14].

2.4. Pure-Tone Audiometric Test

The audiometric data used in this study were originally collected as part of the workers' annual screening audiometric test, and were not intended for research purposes. The audiometric tests were conducted by certified Audiometric Testing Centers (ATC) using an audiometry booth calibrated to the standards set by the Department of Occupational Safety and Health. Workers were required to have a period of quiet for at least 14 h prior to testing. The tests used pure-tone air conduction at frequencies of 500, 1000, 2000, 3000, 4000 and 6000 Hz. The hearing threshold at 8000 Hz was not tested as it was not mandated by law [14].

Normal hearing is defined as air conduction hearing threshold levels of less than 25 dB at all test frequencies. Hearing loss is defined as air conduction hearing threshold levels of more than 25 dB at any test frequency. Hearing loss severity is categorized into mild (26 to 40 dB), moderate (41 to 70 dB), severe (71 to 90 dB) and profound (equal to or more than 91 dB) [25].

The data used in this study were limited to pure-tone air conduction audiograms only, which means that we were not able to confirm the diagnosis of sensorineural hearing loss for those with abnormal audiograms. Hence for the purpose of our investigation, we defined NIHL as bilateral high-frequency hearing loss (3000 Hz to 6000 Hz) with or without audiometric notch. Audiograms showing hearing loss only in the lower frequencies of 500 Hz to 2000 Hz were not considered as NIHL.

In practice, individuals with abnormal audiogram reports are required to undergo a repeat audiometric test within 3 months from the date of the previous audiometric test. Further examinations and investigations are to be arranged if indicated as such [25]. The results of the repeat audiometric test, however, are not part of this study.

2.5. Data Analysis

Data analysis was performed using SPSS Version 23. Statistical significance was set at $p < 0.05$. Categorical data were analyzed using Chi-square or Fisher's exact tests. Differences in the means of variables across three groups were calculated using one-way analysis of variance (ANOVA). Univariate and multivariate logistic regression were used to identify factors associated with NIHL.

3. Results

Our study subjects comprised 494 workers from nine different palm oil mills. Despite the differences in the plant layout for each mill, they generally share a similar processing workflow. The comparison of the noise risk assessment reports of the mills showed nine workstations commonly described as having excessive noise levels: grading area, loading ramp, sterilizer, press station, oil room, kernel station, boiler house, engine room and workshop. However, there were variations in the types of machineries used in each mill, and hence differences in the levels of noise exposure for individuals with similar work descriptions. The ranges of noise level for relevant workstations are summarized in Table 1.

Table 1. Range of noise levels at workstations in palm oil mills.

Workstation	Range of Noise Levels		
	$L_{EQ,8\,h}$ (dBA)	Max Level (dBA)	Peak Level (dBC)
Boiler house	84.4–96.1	106.2–122.3	124.2–143.0
Engine room	84.4–95.4	106.2–118.4	124.2–138.8
Grading area	76.5–81.6	102.7–109.4	116.6–128.2
Kernel station	87.1–93.0	98.6–117.5	122.1–140.7
Loading ramp	81.6–89.9	107.6–113.5	123.0–138.9
Oil room	84.5–90.8	95.1–120.3	120.3–138.4
Press station	85.1–90.5	94.2–122.5	125.1–138.8
Sterilizer	81.4–93.6	104.8–119.4	128.5–138.5
Workshop	77.8–91.7	101.3–121.3	128.6–145.2

Table 2 shows the overall characteristics of the study subjects. All but eight workers were males. Ages ranged from 21 to 59, with an average of 41 years old. The mean work duration was 15 years, with a minimum of 6 months. We categorized the workers into five different groups according to work descriptions: office workers, general workers, maintenance workers, operators, and supervisors. Office workers include managers, clerks, and laboratory staff. General workers include cleaners and landscape workers. Maintenance workers consisted of electricians and mechanics; this group of workers are stationed in the workshops, but also carry out maintenance duties in noisy processing stations within the mills. More than 60% of mill workers are operators who are positioned at various workstations along the processing line. Supervisors spend their working hours in office buildings, as well as in processing stations.

Based on the noise risk assessment reports, only 13% of workers were considered to be in the low exposure group. The moderate exposure group comprised 53.2% of all workers. These workers were either exposed to occasional noise, or were those whose workstation did not exceed the NEL. On an individual level, the daily noise exposure level for this group of workers would fall between 82 and 85 dBA. The high exposure group account for the remaining 33.8% of workers. These workers have been identified in the noise assessment reports to be exposed to hazardous level of noise exceeding the daily NEL of 85 dBA.

Overall, only 24.1% of workers had normal audiogram results for both ears, while 75.9% of them were shown to have some degree of hearing loss either unilaterally or bilaterally, including seven individuals with hearing loss only in the lower frequencies (500Hz to 2000Hz). However, from a total of 375 workers with hearing loss, only 251 fulfilled our operational definition of NIHL.

Table 2. Characteristics of study subjects (N = 494).

Variables	***n* (%)**
Gender	
Male	486 (98.4)
Female	8 (1.6)
Work description	
Office	64 (12.9)
General worker	17 (3.5)
Maintenance	101 (20.5)
Operator	301 (60.9)
Supervisor	11 (2.2)
Age (Range 21–59)	41.03 (10.095) [a]
20–29 years	80 (16.2)
30–39 years	147 (29.8)
40–49 years	126 (25.5)
50–59 years	141 (28.5)
Work duration (Range 0.5–39.4)	14.61 (10.29) [a]
≤5 years	109 (22.1)
6–10 years	123 (24.9)
11–15 years	52 (10.5)
16–20 years	50 (10.1)
>20 years	160 (32.4)
Exposure level	
Low	64 (13.0)
Moderate	263 (53.2)
High	167 (33.8)
Hearing condition (Worse ear)	
Normal hearing	119 (24.1)
Mild hearing loss	188 (38.0)
Moderate hearing loss	154 (31.6)
Severe hearing loss	29 (6.1)
Profound hearing loss	4 (0.2)

[a] Mean (SD).

Table 3 shows the characteristics of the study subjects according to the exposure levels. Mean age and work duration for all three exposure levels were compared using one-way analysis of variance (ANOVA), showing no significant difference between the groups.

Table 3. Characteristics of study subjects according to exposure level (N = 494).

Variables	**Exposure Level**			
	Low ***n* = 64**	**Moderate** ***n* = 263**	**High** ***n* = 167**	
Gender				
Male	57	262	167	
Female	7	1	0	
Work description				
Office	64	0	0	
General worker	0	17	0	
Maintenance	0	97	4	
Operator	0	138	163	
Supervisor	0	11	0	
		Mean (SD)		*p*
Age	41.95 (10.417)	41.77 (9.984)	39.53 (10.034)	0.059 [b]
Working duration	15.14 (10.647)	15.36 (10.428)	14.26 (9.910)	0.551 [b]

[b] One-way analysis of variance (ANOVA).

Table 4 summarizes the laterality and severity of high-frequency hearing loss among the workers. Bilateral hearing loss was detected in 251 out of 368 (68.2%) workers, while the remaining 117 (31.8%) had unilateral hearing loss. In terms of severity, most workers suffered from mild and moderate hearing loss, numbering 49.2% and 41.8%, respectively. The overall prevalence of NIHL among our study subjects was 50.8% (251 out of 494). Stratifying the prevalence according to exposure levels yielded values of 35.9% (23 out of 64) for low exposure, 51% (134 out of 263) for moderate exposure, and 56.3% (94 out of 167) for high exposure groups.

Table 4. High-frequency hearing loss laterality and severity according to exposure level (n = 368).

Variables	**Exposure Level**			**Total, n (%)**	p
	Low (n = 44)	**Moderate (n = 195)**	**High (n = 129)**		
Laterality					
Unilateral	21	61	35	117 (31.8)	<0.039 [c]
Bilateral	23	134	94	251 (68.2)	
Severity					
Mild	31	90	60	181 (49.2)	<0.034 [d]
Moderate	9	91	54	154 (41.8)	
Severe	2	13	14	29 (7.9)	
Profound	2	1	1	4 (1.1)	

[c] Chi-square. [d] Fisher's exact test.

Table 5 shows the factors associated with NIHL among the workers. Univariate logistic regression was used to test each of the variables; age, exposure level, and work duration. Table 6 shows the final model, which included only two factors: age and exposure level.

Table 5. Univariate logistic regression analysis of factors associated with noise-induced hearing loss (N = 494).

Variable	**Crude OR (95% CI)**	p
Exposure level		
Low	1	
Moderate	1.852 (1.052, 3.258)	0.033
High	2.295 (1.266, 4.162)	0.006
Age	1.088 (1.067, 1.110)	<0.001
Work duration	1.062 (1.043, 1.083)	<0.001

Table 6. Multivariate logistic regression analysis of factors associated with noise-induced hearing loss (N = 494).

Variable	**B**	**Adjusted OR (95% CI)**	p
Exposure			
Low		1	
Moderate	0.766	2.150 (1.159, 3.991)	0.015
High	1.242	3.462 (1.784, 6.716)	<0.001
Age	0.091	1.095 (1.072, 1.118)	<0.001

Constant = −4.518; forward likelihood ratio method was applied; no multicollinearity and no interaction; Hosmer Lemeshow test, p = 0.53; classification table 69% correctly classified; area under ROC curve = 75%.

4. Discussion

Our data show an overall NIHL prevalence of 50.8% in a sample consisting of only 33.8% workers exposed to daily noise level exceeding the NEL. In a small study among palm oil mill workers in the neighboring country of Indonesia, the prevalence was lower, at 35%, despite their having more than 75% of workers exposed to daily noise level exceeding 85 dBA [12]. Another study involving a similar population reported a much higher prevalence of 89.3%. However, all participants in that particular study were exposed to hazardous daily noise levels [10]. Both studies defined NIHL using the average hearing threshold at frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. A local study among manufacturing workers exposed to noise exceeding the NEL reported a prevalence of 73.3% [17]. As a comparison, the prevalence among our high exposure group was lower, at 56.3%. The operational definition of NIHL, however, was different compared to our study—air conduction hearing threshold exceeding 25 dB at any frequency, including those with unilateral hearing loss. This may have contributed to a higher prevalence, since more workers would be considered to have NIHL. A more comparable definition of NIHL was used in a study among vector control workers in Malaysia [26]. The authors defined NIHL based on occupational exposure, presence of audiometric notching at 4000 Hz, and bilateral involvement. The prevalence of NIHL was relatively low, at 26.5%. Studies conducted among factory workers in Myanmar and China also reported low prevalences of 25.7% and 28.8%, respectively [16,24]. The participants in these two studies consisted of both low and high noise-exposure groups, comparable to our study participants. It must be noted that a direct comparison of prevalence between various studies is almost impossible due to the dissimilarities in the definition of NIHL, as well as the inclusion criteria for study subjects.

Our operational definition of NIHL is bilateral high-frequency hearing loss with or without audiometric notch. In clinical practice, occupational NIHL is typically characterized as bilateral sensorineural hearing loss, affecting the hearing threshold at 3000 Hz and higher, with the presence of an audiometric notch [27,28]. However, confirmatory audiometric tests, including air and bone conduction, are still necessary in order to confirm such diagnoses, especially in cases where asymmetrical hearing loss is detected [29]. Unilateral hearing loss due to noise exposure is known to occur in situations where the exposure is asymmetrical, for example gunshot noise for firearm handlers or wind noise for drivers [27,28]. In our study population, asymmetrical exposure can occur if personal protective devices are not worn properly, either intentionally or unintentionally. Nevertheless, unilateral hearing loss is more commonly associated with retrocochlear lesions, such as acoustic neuroma, instead of NIHL [28].

NIHL can affect both low and high frequencies. However, the effects on lower frequencies are less common, except in cases with extensive exposure to hazardous noise [28]. High-frequency notch is a typical finding in the audiograms of noise-exposed individuals, although it is not pathognomonic of NIHL [29]. It is worth noting that the definitions of "notch" vary, as described in numerous studies [30,31]. We believe that the lack of a standardized definition of audiometric notch may pose an issue in its application as a criterion for diagnosing NIHL, particularly when using data from screening audiograms alone. In addition, our study participants' hearing threshold levels at 8000 Hz were not tested. This mean that we could not elicit the classical audiogram pattern of recovery at 8000 Hz [27]. More importantly, the notch becomes less apparent in older individuals [28]. Thus, we did not include audiometric notch as a requirement to define NIHL. However, we acknowledge the importance of the audiometric notch as supporting evidence to establish the diagnosis of NIHL in clinical practice, especially in cases where workers are found to have sensorineural hearing loss. Hence, a hearing threshold level of 8000 Hz should be included in the screening audiometric tests for noise-exposed workers.

The findings in this study must be interpreted with caution, mainly due to the fact that we only analyzed data from screening audiometric procedures, as opposed to actual confirmatory audiometric tests. The prevalence that we calculated may have been an underestimation, since we did not include cases with unilateral hearing loss. Conversely, the results of air conduction screening audiometry may produce false positives, leading to an overestimation of prevalence. This is particularly true in cases where the hearing losses detected were actually conductive in nature, or were due to pathological conditions other than cochlear hair cell damage. Given the limitations in our data, we believe that our operational definition of NIHL is a reasonable arrangement to estimate the magnitude of the disease in the study population.

The daily noise exposure level of 85 dBA is widely accepted as the permissible exposure limit in many countries around the world [5,32,33]. Numerous studies have shown that exposure to noise beyond this limit increases the risk of developing NIHL [21,34]. However, some research has suggested that hearing loss can also occur upon exposure to noise between 80 and 85 dBA [27,33,35]. In our study, exposure to noise levels between 82 and 85 dBA was considered as moderate exposure, in relation to the term "excessive noise" introduced in the new Malaysian noise regulation [14]. Interestingly, our data demonstrate the significant effects of both moderate and high exposure levels on the outcome of NIHL. Workers categorized in the moderate exposure group are, by definition, not exposed to daily noise level exceeding the permissible limit, and thus are not required to undergo annual audiometric tests. In practice, this can lead to a significant level of undiagnosed NIHL in the study population. Our findings show that this group of workers actually had more than two times the odds of having NIHL compared to those in the low exposure group when adjusted for age. We acknowledge that this could have been the result of misclassification bias, particularly involving workers who may have been assigned to different workstations throughout their employment. Another possible explanation for this is that we did not measure other confounders, such as smoking, impulse noise, recreational noise exposure, and compliance to hearing protection devices [21,36].

Bivariate logistic regression showed that exposure level, age, and work duration are all significant factors associated with NIHL. However, multivariate logistic regression produced a final model consisting of only exposure level and age. A probable explanation for the inclusion of age and the exclusion of working duration is that these factors are both temporal factors, and thus would be highly correlated. Our findings are comparable with the results documented in several other studies. In Tanzania, the prevalence of NIHL among metal workers was found to be associated with older age groups and noise exposure [15]. In a study conducted among vector control workers in Malaysia, participants were split into two age groups: <40 and ≥ 40 years old. It was shown that age group and noise exposure were significant predictors of NIHL [26]. In Myanmar, NIHL was more prevalent among textile workers aged 35 and older, as well as those with tinnitus. Other factors such as noise exposure, work duration, and smoking were not significant predictors of NIHL [16]. A large retrospective study among mining and oil and gas extraction workers in America also demonstrated results in line with our findings—NIHL was significantly associated with high noise levels and older age groups [37].

Pertaining to the protection of the hearing health of workers in the palm oil manufacturing industry, engineering and administrative control measures alone may not be sufficient. Our data show that a significant proportion of workers stationed along the processing line are still exposed to hazardous levels of noise, and thus would need to be equipped with hearing protection devices. According to the law, employers are responsible for providing education and training regarding noise exposure for workers who are exposed to excessive noise at the workplace, at least once a year. Employers are also required to provide these workers with suitable, efficient and properly maintained hearing protection devices [14]. Although we did not explore the workers' compliance to hearing protection devices, this may have been a contributing factor to the high prevalence of NIHL. A local study conducted among manufacturing workers reported a low compliance rate of less than 40% [38]. In a qualitative study conducted among noise-exposed sawmill workers, it was shown that the workers did not comply to the use of hearing protection devices due to three main factors: comfortability, lack of awareness, and prevention of communication [39]. Hence, there is a crucial need for employers to evaluate the implementation of hearing conservation programs in the workplace to ensure that workers in the high-risk group are adequately protected from occupational noise hazards.

The strength of our study lies in the use of data from industrial noise risk assessments and workers' audiometric screening tests. These are actual data, which would be used to manage noise hazards and guide the implementation of hearing conservation programs at oil mills. Obtaining data from employers also enabled us to get a relatively bigger sample, encompassing all workers with varying levels of noise exposure. This is particularly beneficial in enabling comparisons across different exposure groups.

Since this study was limited to secondary data, we did not manage to include other possible predictors of NIHL in our data analysis. It was also not possible to confirm the diagnosis of NIHL for workers with abnormal audiogram reports.

Overall, the findings in this study outline the need for a precautionary approach when managing the risk of occupational NIHL in the palm oil industry. Occupational doctors and industrial hygienists must consider the risks of workers developing NIHL, despite not being identified as high-risk according to their workplace noise evaluation. We propose that further research should be undertaken related to the risk of developing NIHL in those exposed to excessive noise below the permissible limit, in order to confirm our findings.

5. Conclusions

This study highlights the need for a precautionary approach to better protect palm oil mill workers from workplace noise hazards. Risk stratification based entirely on workplace noise risk assessment reports may lead to inaccurate evaluations and result in the suboptimal implementation of hearing conservation programs. The effectiveness of occupational noise hazard control at all levels must be evaluated to ensure the preservation and improvement of the hearing health of vulnerable group of workers.

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