# Occupational noise-induced hearing loss prevalence and noise abatement techniques in a steel-making plant

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## ABSTRACT

***Background:*** **A high prevalence of noise-induced hearing loss (NIHL) is observed amongst employees in the steel manufacturing industry.**

***Objective:*** **To determine the prevalence of NIHL and current noise abatement techniques implemented at a steel manufacturing plant.**

***Methods:*** **Structured questionnaires were completed by permanent employees at a steel-manufacturing plant for the purpose of collecting information on occupational and medical histories, noise exposure in and outside the work environment, use of hearing protection devices (HPDs), and current noise abatement procedures. A walk-through survey was also conducted to observe implemented noise abatement techniques using the Noise Induced Hearing Loss Regulations of 2003 as a guideline.**

***Results:*** **A total of 17.9% of workers suffered from NIHL (95% CI 11.8% - 22.5%). Administrative controls, lubrication and mufflers were identified by more than 70% of the respondents as control procedures most often implemented by the company. Most of the respondents (77%) used HPDs always and 97% indicated that they fit their HPDs at the beginning of the shift.**

***Conclusion:*** **NIHL remains a significant health problem in this steel industry despite the implementation of noise abatement techniques and the implementation of a noise conservation programme with all the required elements.**

***Keywords:*** **NIHL, noise control, steel industry**

## INTRODUCTION

Noise exposure is a major occupational hazard. Noise-induced hearing loss (NIHL) is irreversible sensorineural hearing impairment caused by a combination of the type of noise (continuous or impact), exposure time, intensity and frequency.[1,2] The scientific literature suggests that exposure to excessive noise contributes to 37% of all adult cases of hearing loss and remains a significant contributor to employment morbidity internationally.[3] Research shows that chronic noise exposure also has significant non-auditory effects such as fatigue,[4] absenteeism,[5] psychological outcomes,[6] hypertension,[7,8] and cardiovascular effects.[9-11]

Occupational hearing loss continues to be among the 10 leading occupational diseases in both Canada and the United States. In the United States, about 11 million workers are exposed to hazardous noise in the work environment.[12] The National Institute for Occupational Safety and Health (NIOSH) estimates that more than 30 million workers (almost 1 in 10) are exposed to hazardous noise levels on the job.[13] In Sweden, about 9% of workers are continuously exposed to hazardous noise levels in the workplace, and approximately 100 million dollars are paid yearly in compensation.[1]

The impact of occupational NIHL is poorly studied in Africa.[14] Research conducted among steel rolling mill workers in Nigeria showed that they were not thoroughly informed about the hazards of NIHL and that they were not keen to use hearing protection devices (HPDs).[2] A recent study in South Africa indicated that there are shortcomings in the standard operating procedures for early detection of employees at risk for NIHL, and that hearing conservation techniques were not utilised properly in the iron and steel industry.[15]

Steel manufacturing is one of the noisiest industries.[16] The main noise sources include fume extraction systems, vacuum systems that utilise steam ejectors, electrical transformers, rolling mills, and ventilation fans. As a result, NIHL is one of the most commonly observed occupational health conditions in workers employed in the steel industry.[16]

The NIOSH has suggested that a more comprehensive set of elements be incorporated in hearing loss prevention programmes, including routine noise exposure assessment, engineering and administrative control of noise exposures

as the primary mechanism of reducing workers' exposure, usage of HPDs, and annual audiometric surveillance and evaluation (feedback on testing results and training on HPD fit and use).[13] In South Africa to date, there have been no broad-based efforts to assess the effectiveness of the approach as outlined in the NIHL Regulations (GN R307 in GG 24967 of 7 March 2003) to prevent hearing loss. It is important that the efficacy of hearing conservation programmes be reflected by the direction and extent of positive change in hearing loss of employees over time.[17]

The purpose of the study was to determine the prevalence of NIHL, obtain historical occupational hygiene noise survey data to determine the extent of noise exposure in the areas studied, and assess if required noise abatement techniques, as stipulated by the Noise Induced Hearing Loss Regulations, were implemented in a steel-manufacturing plant.

## METHODS

This was a descriptive cross-sectional study, which included administration of a questionnaire, a walk-through survey to determine compliance with the recommended noise abatement approach and techniques as stipulated in the NIHL Regulations 2003, and anonymous collection of NIHL data from the on-site clinic of all participants. All permanent employees with base line audiograms were included in the study which took place from 30 June to 26 July 2011.

The structured questionnaire was based on South African National Standard 10083,[18] Noise Induced Hearing Loss Regulations GN R307 in GG 24967 of 7 March 2003,[19] and information obtained from peer-reviewed scientific literature. It consisted of 31 questions, including four from the steel-manufacturing company pertaining to maintenance and fitting of HPDs. The questionnaire covered demographic characteristics, employment history, self-perceived short noise exposure outside the work environment, subjective noise levels in the plant or work area where most work was performed, medical history, usage and maintenance of HPDs, and noise control procedures implemented by the company.

The questionnaires were distributed during a pre-shift meeting; some were given to the supervisors of each section to distribute to employees who were absent from the meeting. The questionnaire was explained to the employees and study participants signed an informed consent form before they completed it. Some of the employees took the questionnaires with them and were requested to return them to the supervisor within one week. Unique study numbers were assigned to study participants and were linked to employee numbers in order obtain audiogram records from the on-site clinic. Both numbers were recorded on the first page of the informed consent form attached to the questionnaire. The occupational health practitioner (OHP) detached the page with these numbers after providing the required NIHL information from the medical file.

Four hundred employees were given questionnaires, and 134 (33.5%) completed questionnaires were returned. The completed questionnaires were taken to the company's on-site clinic where the OHP identified whether the employee had presented with NIHL or not, from the medical records. The NIHL status of each employee was indicated at the back of the questionnaire.

Employees with a 5% shift from the baseline audiogram were classified to have NIHL, despite the fact that the NIHL Regulations state that a 10% shift from the baseline audiogram should be considered as NIHL. This approach was followed because, in this steel-manufacturing company, a 5% shift from the baseline audiogram indicated that actions to prevent further NIHL should be initiated. All audiometry tests were conducted according to SANS 10083, using the Everest audiometric testing program.

The collected data from the questionnaires were double entered into Epi-data and transferred to STATA 12. Descriptive statistics were used to report data as means, standard deviations and frequencies where appropriate. Proportions of people with NIHL were calculated using STATA 12.

Ethical approval (number 122/2010) for the study was obtained from the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria. Permission was also obtained from the steel-making plant to conduct the study.

## RESULTS

Table 1 summarises the characteristics of the study participants. Of the respondents, 81.3% were male and 18.7% female. There were 67.2% employees in the age group 31-50 years. The majority of employees had tertiary education (55.3%) and more than a third (35.8%) had secondary education.

**Table 1. Characteristics of study participants (N = 134)**

| Characteristic | n | % |
|---|---|---|
| **NIHL** | | |
| Yes | 24 | 17.9 |
| No | 110 | 82.1 |
| **Sex** | | |
| Male | 109 | 81.3 |
| Female | 25 | 18.7 |
| **Age (years)** | | |
| 21-30 | 29 | 21.6 |
| 31-40 | 46 | 34.3 |
| 41-50 | 44 | 32.9 |
| 51-60 | 15 | 11.2 |
| **Education level** | | |
| No schooling | 5 | 3.7 |
| Primary | 7 | 5.2 |
| Secondary | 48 | 35.8 |
| Tertiary | 74 | 55.3 |

## Noise-induced hearing loss

As shown in Table 1, 18% of the respondents (n = 24) had NIHL (95% CI 11.8% - 25.5%). The average no. of years employed for those with NIHL was 18, compared to six years for those without NIHL. Table 2 summarises the prevalence of NIHL stratified by sex and job categories. Operators and electricians had the highest prevalence rate in terms of NIHL (6% and 3%, respectively).

Three per cent of the respondents did not undergo a baseline-hearing test when they joined the company and 4.5% were not informed about their baseline audiogram results (Table 3). A total of 33% of the participants had no periodic audiograms.

## Non-occupational noise exposures

Around one-third (37%) of the participants were exposed to loud music on a daily basis and 15.7% used earphones when listening to music; 41% claimed to drive their cars daily while windows were open, while 10.4% reported to be involved in shooting or hunting exercises at least once a month without wearing HPDs (see Supplementary Table 1 online).

**Table 2. Prevalence of NIHL by sex and job category (N=134)**

| Variables | n | % |
|---|---|---|
| **Sex** | | |
| Females | 5 | 3.7 |
| Males | 19 | 14.2 |
| **Job category** | | |
| Artisans | 2 | 1.5 |
| Boilermakers | 1 | 0.8 |
| Coordinators | 2 | 1.5 |
| Electricians | 4 | 3.0 |
| Fitters | 2 | 1.5 |
| Human resources | 1 | 0.8 |
| Maintenance | 2 | 1.5 |
| Furnace Operators | 9 | 6.0 |
| Tappers | 1 | 0.7 |

**Table 3. Employees responding "Yes" to medical surveillance questions (N=134)**

| Variables | n | % |
|---|---|---|
| Exposed to noise at previous job | 59 | 44.0 |
| Entry medical examination | 129 | 96.3 |
| Baseline audiogram | 130 | 97.0 |
| Normal hearing status results | 126 | 94.0 |
| Results communicated | 128 | 95.5 |
| Subsequent audiogram(s) | 90 | 67.2 |
| Hearing test(s) conducted by an OHP | 103 | 76.9 |
| Hearing problem experience(s) | 21 | 15.7 |
| Threshold shift | 75 | 56.0 |

**Table 4. Usage of HPDs (N=134)**

| Variables | n | % |
|---|---|---|
| **Frequency** | | |
| Always | 103 | 76.9 |
| Occasional | 16 | 11.9 |
| Seldom | 3 | 2.2 |
| Never | 12 | 9.0 |
| **Type** | | |
| Earplugs | 103 | 76.9 |
| Earmuffs | 16 | 11.9 |
| Moulded | 3 | 2.2 |
| Other | 12 | 9.0 |
| **Duration of use (hours)** | | |
| 1 | 13 | 9.7 |
| 2 | 1 | 0.7 |
| 3 | 0 | 0.0 |
| 4 | 8 | 6.0 |
| 5 | 3 | 2.2 |
| 6 | 11 | 8.2 |
| 7 | 8 | 6.0 |
| 8 | 90 | 67.2 |
| **Fitting** | | |
| Beginning of the shift | 130 | 97.0 |
| No need to wear | 4 | 3.0 |
| **Cleaning frequency** | | |
| Always | 98 | 73.1 |
| Once a week | 33 | 24.6 |
| Once a month | 3 | 2.2 |

## Control procedures

Administrative controls, lubrication and mufflers were identified by 78.2%, 75.0% and 73.9% of the respondents, respectively, as control procedures most often implemented by the company to reduce noise levels. Respondents also indicated that substitution (65.8%), sound absorbing materials (67.3%), and controls along the path (70%) were implemented within the plant. In this steel-making company, employees with NIHL were redeployed to other sections of the plant were noise levels were lower.

## Medical histories

Only 12% reported to have suffered from measles, mumps and 8% from meningitis. Eight per cent occasionally experienced pain in their ears, while 7% had a family member who suffered from hearing loss (see Supplementary Table 2 online).

## HPD fitting and hygiene

Most of the respondents (76.9%) used HPDs always and 97% indicated that they fit their HPDs at the beginning of the shift, and that fitting of their HPDs was being done according to the instructions on the pack or as taught at

the company (Table 4). More than half (56.7%) reported that their hearing improved within 12 hours after leaving the workplace. Only 24.6% of the respondents reported that they cleaned their HPDs once a week; 2.2% cleaned them once a month.

### Area noise levels

The average noise levels reported for different sections during the occupational hygiene survey are shown in Table 5. The highest noise level of 91.0 dBA was reported for the electrical and mechanical workshop (M2). Noise levels in raw materials (M1) and crusher and furnace (M4 – PSP) sections were 1.7 and 2.6 dBA lower than those in the electrical and mechanical workshop, respectively. The reported noise level for the control and mixing section was more than 10 dBA lower than in the other plant sections.

### Noise abatement

The noise abatement techniques observed during the walk-through survey are summarised in Table 5. The following controls were implemented in all sections: administrative controls, personal protective equipment (PPE), job rotation, and control along the path. Substitution was implemented in M2, and the control and mixing section (M3). Only elimination and acoustical enclosures were implemented in M3.

## DISCUSSION

The results of this study and the occupational hygiene survey confirmed that noise was a significant occupational hazard in this steel-manufacturing plant despite continuous efforts by management to implement noise abatement techniques. Eighteen percent of employees who took part in this study had NIHL levels higher than 5% from the baseline. No peer review studies on the prevalence of NIHL in the steel and iron industry have been conducted in South Africa. However, the prevalence of NIHL in this study (18%) is comparable to the 16% of disabling hearing loss in adults that is attributed to occupational noise worldwide.[20] A higher prevalence (33.5%) of NIHL was observed in a study conducted in a Brazilian steel and iron industry than in this study.[21]

The level of education or the number of years attending school was positively associated with a decline in the risk of developing NIHL.[22] The reason for this might be that employees with higher literacy levels are able to read, follow instructions, and understand demarcations or signs pertaining to noise and its related health effects. However, despite high literacy levels in these workers, a significant number of them were affected by occupational noise. The

**Table 5. Area noise levels measured during 2011 annual occupational hygiene survey and abatement techniques per plant section**

| Plant section | Noise rating level ($L_{avg}$) | Job category | Abatement techniques |
|---|---|---|---|
| M1 (Raw materials) | 89.3 dBA | Material controllers<br>Artisans<br>Apprentices<br>Production workers<br>Buyers<br>Plant operators<br>Accountants<br>Human resource | Administrative controls<br>PPE<br>Job rotations<br>Controls along the path |
| M2 (Electrical and mechanical workshop) | 91.0 dBA | Electricians<br>Boilermakers<br>Artisans<br>Apprentices<br>Fitters | Administrative controls<br>PPE<br>Job rotations<br>Controls along the path<br>Substitution |
| M3 (Control and mixing plant) | 77.0 dBA | Plant operators<br>Engineers<br>Coordinators | Administrative controls<br>PPE<br>Job rotations<br>Controls along the path<br>Substitution<br>Elimination<br>Acoustical enclosures or barriers |
| M4 – PSP (Crusher and furnace) | 88.4 dBA | Furnace operators<br>Crusher plant workers<br>Fitters | Administrative controls<br>PPE<br>Job rotations<br>Controls along the path |

respondents might have interpreted tertiary education as any form of education, training or certificate received after leaving formal schooling, even if obtained at the workplace. Further studies need to be conducted to evaluate the role of education as a predictor for NIHL.

More males than females are employed in the steel-manufacturing industry due to the nature of the work that requires physical strength. In the steel production and manufacturing industries, the literature indicates that a heavier burden of NIHL is evident in males than females because more men are employed in jobs that require them to work in those areas of the steel-making industry where noise levels are high.[23] It was therefore not surprising that males had an almost four-fold higher prevalence of NIHL than females.

"The highest exposed employees were operators, electricians and fitters."

During the walk-through survey, it was observed that noise exposure level varied depending on job category and males were predominant in all the sections of the company. The noise levels reported in an annual occupational hygiene survey of 2011,[24] completed prior to this study, confirmed the observation. Average noise levels of three out of four plant sections exceeded the noise-rating limit of 85 dBA as stipulated in the NIHL Regulations. The highest exposed employees were operators, electricians and fitters. The prevalence of NIHL amongst these workers was also the highest and may be attributed to 8-hr equivalent noise exposure levels above the noise-rating limit.

Almost all the respondents claimed to have always worn HPDs when performing work that generated noise. This might have been a result of enforcement of health and safety procedures within the company. However, HPD usage information was self-reported, and this might have introduced reporting bias due to social desirability.[25] The most common explanation for inconsistent use of HPDs was discomfort and pain in the ears. Different types of HPDs should therefore be made available to cater for anatomical variations.[26]

Further support of incorrect use of HPDs was that 56.7% of respondents reported that their hearing improved within 12 hours after work. The improvement of hearing might be indicative that temporary loss of hearing after exposure to noise (temporary threshold shift) was present during the previous shift.

## Medical surveillance

The NIHL Regulations of 2003, Regulation 8, requires that an employer should establish and maintain a system of medical surveillance for all employees. The medical surveillance should consist of a baseline audiogram, a periodic audiogram, and an exit audiogram test.[18] Periodic health examination should be mandatory for all workers, and a participation rate of nearly 100% should be expected for all workers exposed to noise levels above the noise-rating limit.[23] Three percent of the respondents did not undergo a hearing test when they joined the company. This suggests that there is a shortfall in the company's hearing conservation programme. A concern is that 4.5% of the respondents were not informed about their baseline audiogram results. This might affect employees' knowledge about their own hearing status and precautionary measures to be taken to prevent the development or exacerbation of NIHL. A further concern was that 33% of the participants did not have a subsequent periodic audiogram. In these cases, changes in hearing ability would not be detected at an early stage. With annual audiometric testing, it is possible to detect changes in hearing ability before the development of clinically significant hearing loss.[27] In Turkey, the proportion of employees that undergo annual hearing tests in the iron and steel industry is 19.7%. The proportion of employees without periodic audiometric testing at the study site was much lower than this, which might be an indication of the company's effort to implement or comply with the NIHL Regulations.[28]

## Noise control procedures

The observations during the walk-through survey and feedback received from the majority of employees were proof of the company's effort to reduce occupational noise exposure of employees. Control measures were persistently applied; however, the effectiveness thereof must be evaluated regulary.[18] Engineering and administrative controls are the most effective control procedures against excessive noise exposure. Only if engineering and administrative controls are not reasonably practical, should the company implement the use of HPDs.[2] The desirable hierarchy of control measures implemented is evidence that the company applies the required control measures.

A concern is that some of the employees did not know which noise control procedures were implemented within the company. This may indicate that the induction programme did not cover the legislative requirements thoroughly in terms of noise control procedures. The importance of education programmes to prevent NIHL cannot be stressed enough. No employee can be expected to assist with the implementing and maintenance of noise control programmes if he or she does not know the control procedures and programmes that are implemented within the company.

## Non-occupational noise exposures

Literature shows that non-occupational activities such as shooting exercises, powerboats, loud music, lawn mowers, and flying of private aircraft contribute to the total noise exposure of occupationally-exposed workers.[29] Research indicates that exposure to loud music leads to symptoms such as tinnitus and hearing loss and this may add to an individual's cumulative noise dose if encountered regularly.[30,31]

Neitzel et al.[31] characterised non-occupational exposures associated with sporadic activities, depending on the duration and magnitude of the noise. Different recreational activities may cause increased temporary threshold changes on hearing or may even cause NIHL if temporary threshold shift occurs before the next shift. Scientific studies have proven beyond reasonable doubt that recreational gun shooting produces sensory hearing loss by damaging hair cells in the cochlea if HPDs are not used.[32] Almost 11% of the respondents were involved in recreational gun shooting which might have had a negative impact on their hearing ability.

Non-occupational noise exposures have a high potential to add to the daily noise dose and to increase the risk of developing NIHL. Only 41% admitted to driving cars while widows were open. Noise levels while driving a convertible car or a car with open windows ranges from 82 to 92 decibels and may therefore contribute to the development of NIHL.[33] Eleven percent of the participants rode motorcycles without HPDs. Noise around the motorcycle helmet due to wind turbulence is 90 decibels at 60 km/h and increases linearly when plotted against the log of speed, to reach 110 decibels at 160 km/h.[34] To encourage behavioural changes, the company needs to institute education programmes pertaining to the duty of care of non-occupational noise exposure and its consequences. This may have a positive impact on the company's efforts to reduce the prevalence of NIHL.

## Medical histories

Studies have shown that some infectious diseases, like measles and mumps, are associated with acute hearing loss,[35] and that these infections may negatively affect hearing ability with age or might cause gradual hearing loss that can remain unobserved for years. Twelve percent of the respondents had suffered from such diseases. Meningitis is a risk factor for hearing loss in childhood and this can be a progressive problem.[36] Only 7.5% of employees reported to have suffered from meningitis and are therefore more likely to develop NIHL in adulthood. The evidence that hearing loss can be hereditary[36] makes the 6.7% of the respondents with a family member that had suffered from hearing loss or deafness more susceptible to develop NIHL. Such a link and the possible impact thereof on a company's NIHL prevalence rate cannot be ignored. Ototoxic antibiotics account for about 3-4% of NIHL in adults.[37] Only 1.7% of workers were on antibiotics and a possible causal association between NIHL and antibiotics intake needs to be investigated further to establish if any causal associations exist for this study population.

## Hygiene practices

Good hygiene practices, such as cleaning and storage of HPDs, are of utmost importance. Failure to clean HPDs regularly may cause ear infections and increase the possibility of hearing loss. Occupational health education should cover the importance of personal hygiene, and signs and symptoms of exposure to noise.[19]

"Failure to clean HPDs regularly may cause ear infections and increase the possibility of hearing loss."

## Limitations

The findings of this study were based on self-reported answers from questionnaires, which may lead to misclassification of disease and exposure status. For example, people with NIHL might have underestimated their non-occupational noise exposure activities. Data associated with alcohol intake, smoking, hypertension, and other potential confounders were not collected. The low response rate might have affected the internal validity of the study. Supervisory involvement during data collection might have influenced the attitude of employees to their general duty of self-care in terms of noise protection and reported prevalence since some questionnaires were given to the supervisors to distribute to the employees who were absent during the pre-shift meeting.

## RECOMMENDATIONS

1. Collaborations between employees and management should be improved in order to curb the prevalence and the incidence of NIHL, i.e. proper use and maintenance, and reporting of failures of noise abatement techniques.
2. During the employee's medical entry examination, the medical history and non-occupational noise exposures should not be ignored because they might increase the risk of an employee developing NIHL.
3. Employees should be thoroughly trained in the correct use and time of fitting of HPDs.

## CONCLUSION

The fact that one in five employees has NIHL may be indicative that some elements of the stipulated noise conservation

programme are not adhered to, or that non-occupational exposures might have contributed to the observed NIHL, or that the occupational hygiene survey reported noise levels were inaccurate. A holistic approach, i.e. medical management, occupational hygiene monitoring, and administrative and engineering control procedures, is required to effectively manage NIHL cases in steel-making plants.


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## DECLARATION

The authors declare no conflicts of interest.

## LESSONS LEARNED

- Adherence to all elements of the current stipulated noise hearing conservation programme is essential to increase effectiveness thereof
- NIHL research in the steel and iron industry in South Africa is often neglected
- Because periodic audiometric tests conducted by the company do not include all the employees, it might not be possible to detect changes in hearing ability before the development of clinically significant hearing loss, which might lead to an increased burden of NIHL in the company

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