Noise-induced hearing loss and hearing conservation in the iron and steel industry in South Africa

GE Mizan[1,2], O Abrahams[1,2], G Sekobe[1,2,3], S Kgalamono[1,2], M Ndaba[1,2], J Manganyi[1], K Renton[1,2], K Wilson[1]

[1] National Institute for Occupational Health, National Health Laboratory Service, Johannesburg, South Africa
[2] School of Public Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa
[3] University of Pretoria, School of Public Health, Pretoria, South Africa

Correspondence: Mr Gabriel Mizan, NIOH, PO Box 4788, Johannesburg, South Africa, 2000.
e-mail: gaby.mizan@nioh.nhls.ac.za

ABSTRACT

Background and Purpose: **The iron and steel industry in South Africa has been identified as one of the highest risk industries in terms of noise induced hearing loss (NIHL). The National Institute for Occupational Health was commissioned by the Department of Labour to audit the current noise exposure levels and hearing conservation practices in eight major producers of iron and steel, and to make recommendations regarding prevention strategies.**

Methods: **The audit was conducted in two parts: the noise exposure levels and hearing conservation practices were assessed by the occupational hygiene department. The occupational medicine department assessed the hearing conservation policies and procedures, reviewed employees' medical records to ascertain the number of NIHL cases, and conducted verification of audiograms on a sample of employees working in noise zones.**

Results: **Area noise levels exceeding 105 dB(A) were measured in four of the eight workplaces. The estimated average annual incidence of NIHL varied from 0.7 - 8.3/1000/year. All companies did baseline, periodic and exit audiometric testing, but there were notable discrepancies between companies and verification audiograms and differences of more than 20 dB(A) were found. Although information and training on noise was reportedly done in all worksites, a high proportion of workers could not demonstrate correct fitting of hearing protection devices or recall when last they were trained.**

Conclusion: **A detailed standard operating procedure should be implemented for medical surveillance for NIHL with action timelines that initiate remedial processes prior to employee developing compensable disease. Aggregated audiometric testing results should be communicated to managers and health and safety teams to provide guidance to prioritise areas for control measures. A quality assurance programme for audiometric testing must be implemented. An evaluation tool to measure the effectiveness of the noise and hearing conservation training provided to employees, including contracted employees, should be adopted.**

Keywords: **audiometric testing, hearing protection devices, percentage loss of hearing, noise exposure**

INTRODUCTION

The iron and steel industry is one of the largest employers in South Africa, with approximately 55 000 employees working in the primary iron and steel production sector.[1] Some of the occupational hazards include temperature extremes, toxic or corrosive substances, respirable airborne contaminants and high levels of noise.[2]

The effects of excessive exposure to noise on hearing are well documented in the literature.[3] Continuous exposure to noise levels exceeding 85 dB(A) may lead to temporary and permanent noise-induced hearing loss (NIHL).[4,5] For this reason, the Department of Labour (DoL) Noise Induced Hearing Loss Regulations prescribe that all employees who are exposed to noise levels equal to or higher than 85 dB(A) undergo medical surveillance.[6]

Non-auditory effects of noise exposure include hypertension, psychological effects (annoyance, stress), impaired communication, reduced productivity and increased safety risks.[2,7] No studies were found in the literature on NIHL in the iron and steel industry in South Africa, but work has been done in other developing countries. For example, a case-control study of 50 steel factory workers in Indonesia found that 21 of 25 workers (84%) from the steel production department had NIHL, compared to 1 (4%) from the administration department.[8] Another study among Indian iron and steel enterprises found that over 90% of workers engaged in various processes of casting and forging showed hearing loss in the noise-sensitive medium and high noise frequencies.[9]

A cross sectional study among steel factory workers in the United Arab Emirates investigated noise levels, annoyance, awareness and hearing conservation practices among

Table 1. Iron and steel participating companies

Company	Industry	No. of workers (including contractors)*
A	Primary Iron & Steel	>5000
B	Primary Iron & Steel	<2000
C	Primary Iron & Steel	<2000
D	Secondary Iron & Steel	<2000
E	Primary Iron & Steel	2000 - 5000
F	Primary Iron & Steel	2000 - 5000
G	Primary Iron & Steel	2000 - 5000
H	Primary Iron & Steel	2000 - 5000

*Exact figures are not shown for confidentiality reasons

468 steel workers from two factories. The study found that about 89% of the workers were exposed to levels exceeding 85 dB(A) and that 45% of them had never used hearing protection devices. It also found that 58% of the workers experienced moderate or high degrees of annoyance.[10]

Following an initial assessment by the South African Department of Labour (DoL) in the iron and steel sector, the National Institute for Occupational Health (NIOH) was commissioned to evaluate NIHL and hearing conservation practices in this sector. The aims of the study were to verify the current designation of noise zones and assess workers' exposure to noise by conducting general area and personal noise measurements; to audit the current hearing conservation practices in each company; to determine the extent of NIHL diagnosed by the companies over the past decade; to verify records of current hearing threshold levels of workers by independently conducting audiometric testing; and to compile recommendations for improvement of existing hearing conservation practices that can be implemented in the South African iron and steel industry.

Figure 1. Taking an area noise level measurement at one of the iron and steel companies

METHODS

A cross-sectional study was conducted in seven primary producers and one secondary iron and steel producer, selected by the DoL from eight provinces in South Africa. The number of permanent employees in the companies ranged from approximately 250 to 7000 with, in most cases, a similar number of contracted employees (Table 1). The study was carried out jointly by the occupational hygiene and occupational medicine departments of the NIOH.

Occupational hygiene

At each company, the NIOH occupational hygiene team conducted a walkthrough observation and short interviews with workers to assess hearing conservation practices, and reviewed the previous Approved Inspection Authority (AIA) survey reports. A questionnaire was completed with the health and safety manager, covering the following aspects of the company's hearing conservation programme (HCP): information and training, assessment of exposure, AIA survey reports and recommendations, medical surveillance, hearing protection equipment, and policies and procedures.

Spot area noise measurements were taken with a Quest type 1 sound level meter (Figure 1) to verify the current demarcation of areas as noise zones. The meter was positioned at the task location or close to the worker's ear, as appropriate, and a measurement was taken over a long enough time period to be representative of the noise being measured. Personal noise dose measurements were performed on employees working in noise zones. Employees were selected from different departments known to have noise levels exceeding 85 dB(A) and representing different homogenous exposure groups (HEGs). The purpose of these measurements was to ascertain the potential exposure of individuals performing work in designated noise zones. The dosimeter was placed on the worker's shoulder, close to the ear, and measurements were taken over a sufficiently long time to be representative of the worker's exposure. The dosimetry measurements were carried out using CEL dBadge, type 2 dosimeters.

Sampling methodology was based on SANS Code of Practice 10083, 2013: "The measurement and assessment of occupational noise exposure for hearing conservation purposes".[11] All the sound level instruments were externally calibrated by a SANAS accredited laboratory and the calibration was checked before and after measurement, using an acoustic calibrator.

Short interviews were conducted with employees that were fitted with noise dosimeters to ascertain their level of training, awareness and competency in various aspects of the company's HCP. During the interviews the workers were asked to recall when they were last trained on noise and to demonstrate how to fit their hearing protectors. They were also asked about the health hazards related to noise exposure and if they had any concerns or experienced difficulties with their hearing.

Table 2. Area noise measurements in eight iron and steel companies

Company	Number of measurements	Max Leq, dB(A)	Median Leq, dB(A)	Percent (%) > 85 dB(A)
A	26	100	93	87
B	49	102	94	100
C	66	102	88	50
D	32	108	94	87
E	31	100	83	68
F	108	105	85	58
G	27	107	87	78
H	68	112	87	92

Occupational medicine

The audit carried out by the NIOH occupational medicine team comprised three parts: an assessment of the hearing conservation policy and procedures; a medical record review; and an audiometric testing verification.

Assessment of the hearing conservation policy and procedures comprised interviews with the company's health and safety personnel and clinic staff members, as well as a review of the existing written hearing conservation policy (if available). This was done by administering a hearing conservation checklist that assessed details of the information and training programme offered. It also assessed the medical surveillance programme and action plans in the case of threshold shifts being detected. Finally, the hearing conservation checklist looked at record keeping and referral pathways for employees diagnosed with NIHL. Certification of nurses to perform audiology testing and calibration certificates for the audiology equipment were also checked.

A sample of 100 employees was selected from the noisiest departments in each company (as ascertained from the occupational hygiene assessment part of the study). Following consent, a medical record review was performed to establish whether baseline and periodic audiograms were recorded, and if actions were taken when a hearing threshold shift was noted. Cases of NIHL diagnosed and submitted for compensation by the company over the past 10 years were identified and, with consent, these medical files were also reviewed to ascertain whether appropriate interventions had followed the diagnosis.

Lastly, audiometric testing was conducted by an independent third party on a sample of employees who had been part of the medical review to compare the in-house company audiograms with those conducted by the external service provider. Differences in hearing thresholds were assessed at each sound frequency.

Ethics approval for publication of this study was obtained from the University of the Witwatersrand Human Research Ethics Committee.

RESULTS

Noise exposure

A total of 407 area noise level measurements and 120 personal noise dose measurements were taken in the eight companies. Of the area measurements, 261 (64.1%) were higher than 85 dB(A) and 90 measurements (22.1%) were higher than 95 dB(A). Areas where noise levels were equal to or exceeded the 85 dB(A) regulated limit were sign-posted as noise zones, and workers were observed using hearing protection devices, as stipulated in the NIHL Regulations. Of the 120 personal noise dose measurements that were taken, 97 (80.8%) were higher than the occupational exposure limit of 85 dB(A). High variability was observed between companies in the percentage of measurements exceeding 85 dB(A), as shown in Tables 2 and 3. It was also noted that higher area noise levels tended to coincide with higher personal noise dose levels, as illustrated in Figure 2.

Training and awareness

All eight companies had training programmes conducted by a health and safety officer or qualified trainer. However, none of the eight included, in their noise and hearing

conservation training programmes, all eight basic components stipulated in the NIHL Regulations. Four companies reported that they conducted re-training on identification of a 5% loss of hearing (PLH); evidence of this was found in the employee's file in only in a small number of cases. Only half of the companies had implemented formal evaluation of the training by means of a competency test.

A total of 108 short interviews were conducted with workers to assess the level of training and awareness with regard to noise and hearing conservation programmes. Although the vast majority of workers interviewed (n=104; 96.3%) understood the health risk related to noise exposure, 43 workers (39.8%) could not recall when last they were trained. The same number of workers (n=43) failed to demonstrate the correct way of inserting hearing protectors in the ears. A total of 30 workers (27.8%) said that they were concerned about noise in their work environment and 12 (11.1%) reported difficulties with their hearing.

Table 3. Personal noise dose measurements in eight iron and steel companies

Factory studied	Number of measurements	Max Leq, dB(A)	Median Leq, dB(A)	Percent (%) > 85 dB(A)
A	15	97	89	77
B	15	98	91	88
C	12	99	85	62
D	15	102	92	91
E	15	97	88	48
F	12	96	85	50
G	23	103	89	63
H	13	102	94	63

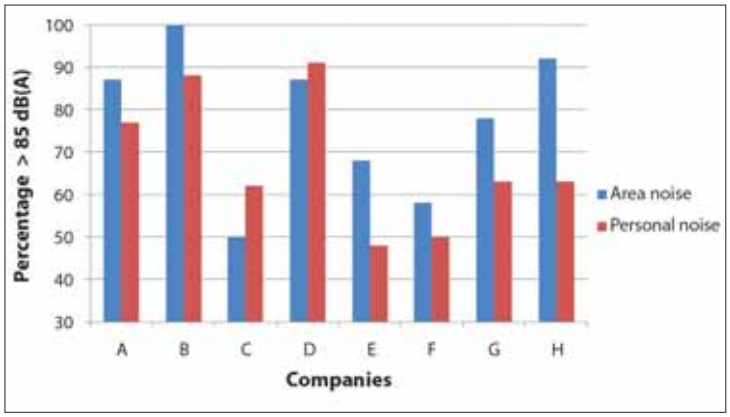

Figure 2. Comparison of the area and personal noise dose measurement per company

Medical surveillance

All eight companies had medical surveillance programmes in the form of audiometric testing at baseline, periodically, and at exit medical assessment. Audiometric testing was done in-house by trained occupational health nurses, using equipment based in the companies' medical stations. In four of the companies, periodic audiograms were carried out annually for all staff, including office workers. Only three companies showed evidence of periodic audiometric assessments being aligned and informed by input from occupational hygiene noise surveys.

In all the companies, audiometric tests were reviewed by an occupational health practitioner for individual analysis. However, the actions taken by companies following the detection of hearing decline varied considerably. The results from the records reviewed, regarding action plans for declining hearing thresholds, are summarised in Table 4.

Audiometric verification

The differences in dB found between the in-house and

Table 4. Actions taken following hearing decline detected during periodic audiometric testing

	Evidence of threshold shift <10 PLH n	Recorded in employee's medical file %	Test repeated after no exposure to noise %	Diagnostic audiogram conducted %	Additional training provided %
A	10	80	40	60	10
B	37	8	8	0	8
C	11	27	0	9	23
D			Unavailable		
E	21	24	15	9	0
F	10	50	10	0	50
G	26	4	4	0	4
H	5	83	17	67	0

Table 5. Comparison of in-house audiometric tests with those carried out by an external service provider

	A	B	C	D	E	F	G	H
Audiograms compared (n)	16	20	20	19	24	21	20	12
Concordant (n)	8	0	4	0	2	2	4	0
10-19 dB difference (n)	3	3	10	7	11	14	14	6
20-29 dB difference (n)	5	7	6	9	8	3	2	4
30-39 dB difference (n)	0	4	0	1	3	1	0	2
>40 dB difference (n)	0	6	0	2	0	1	0	0

Table 6. Company interventions on employees identified with a 10 PLH or more

Company	Employees with NIHL n	Referred for compensation %	Provided training %	Relocated %
A	37	100	22	11
B	21	86	0	0
C	9	100		NC*
D	10	100		NC*
E	7	100	14	29
F	7	86	43	0
G	15			NC*
H	6	83	0	0

*NC: no consent was obtained from employees for their files to be reviewed.

external service provider audiograms are summarised in Table 5. Only 20 (13.2%) of the 152 audiograms that were compared were concordant. Most audiograms (n=68; 44.7%) varied by 10-19 dB, averaged across the different sound frequencies; the remainder (n=64; 42.1%) varied by more than 20 dB.

Noise-induced hearing loss

According to Circular Instruction 171, NIHL is compensable at or above 10 PLH. This is usually calculated from the baseline and takes into account the hearing loss at the sound frequencies 0.5, 1, 2, 3 and 4 kHz, as provided by the audiogram. These are then added to determine PLH which is then used to determine the permanent disablement and compensation entitlement.[12]

Information on cases diagnosed in the past 10 years (2002-2012) was obtained from the companies to determine the burden of NIHL. The results are summarised in Figure 3. In two companies none of the files from the NIHL cases was available for review as employees had not consented, however compensation forms that had been submitted to the Compensation Commissioner could be reviewed. In Company H, information and files were only available from 2008 (not shown in Figure 3), and Company C only began operating in the late 1990s so NIHL from exposure in the company would not be expected until late 2000.

As records from contracted employees were not available for this study, the figures in the graph represent only company employees.

Companies' interventions following an identified 10 PLH, as reflected on employees' records, are summarised in Table 6.

The associations between incidence of NIHL by company and noise exposure, and evidence of companies acting on hearing loss, were tested using Pearson's correlation.

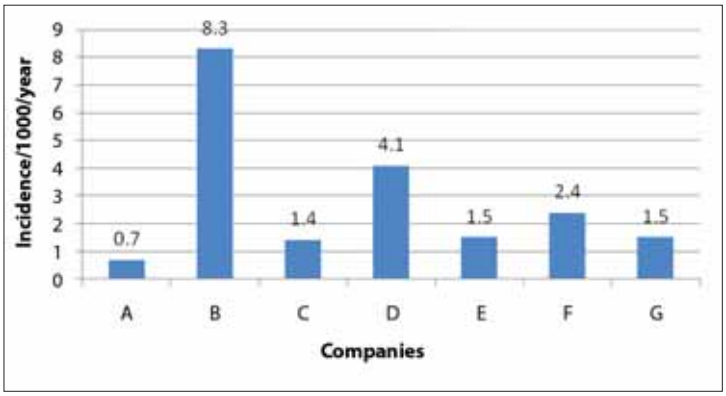

Figure 3. Estimated average annual incidence of noise-induced hearing loss in seven of the companies audited

Correlations were strongest between personal and area noise levels and annual incidence of NIHL per year (r=6.2) indicating that, as noise levels increased, so did NIHL. A weaker correlation (r=4.6) was found between incidence of NIHL and evidence of companies acting on hearing loss in terms of notes in employees files. There was a negative correlation between training provided and incidence of NIHL (r=-6.2), indicating that, where more training was provided, the incidence of NIHL was lower.

Noise control strategies

In all companies, the most common method of controlling exposure to noise was the use of hearing protection devices (HPDs). Three main types of HPDs were used: reusable earplugs, earmuffs, and custom-made hearing protectors. Most companies did not have a written procedure, or workers' involvement, with regard to the selection, issuing, storage and care of HPDs. Several observations of poorly maintained earplugs, as well as poor fitment, indicated that additional training was required. In some companies, HPDs

Figure 4. Double glazed control room

signage was not always clearly visible and/or covered with dust. It is, however, important to note that workers were generally observed using HPDs in demarcated noise zones.

A few instances of the use of engineering methods to control noise were noted. For example, one of the engineering methods most commonly used was a double glazed control room which provided a relatively quiet refuge – up to 20 dB(A) reduction in noise levels – to operators. In one company, fan exhausts fitted with silencers resulted in a noticeable 11 dB(A) reduction in noise levels, compared to untreated fans (Figures 4 and 5).

DISCUSSION

This study confirmed that employees in these eight major iron and steel companies might be at risk of acquiring NIHL. However, the reported incidence rate of NIHL was lower than expected when compared to other studies, considering the high levels of area and personal noise exposure levels that were measured.[8,9] For example, a study in the iron and steel industry in India reported more than 90% of workers with significant hearing loss at the medium and high sound frequencies.[13] The reason for the lower-than-expected incidence is unclear, but under-reporting and short durations of employment in the individual companies might be possible explanations, as well as higher levels of compliance with regard to the use of hearing protection, compared to those reported in other studies.[9,10,14]

The study provided an opportunity to analyse current hearing conservation practices; some companies had more comprehensive programmes than others. It also provided an opportunity to assess if companies could translate policy intentions into good governance and practices. For example, early intervention by occupational clinic staff when first indications of hearing loss are noted, even before the 10 PLH is reached, was one good practice, beyond the minimum statutory requirements that was observed.

The comparison of in-house audiometric tests with those conducted by an external service provider showed large difference in the results (in some cases more than 40 dB) between the two audiometers. Some of the contributing factors to these differences might have been related to the testing conditions, such as noise exposure before testing, equipment calibration, audiometric staff competency and factors affecting employees' hearing, such as ear infections. Currently, no reference body exists for audiometric testing in the workplace and no gold standard testing facility has been identified. These results are therefore a measure of repeatability rather than validity, as the external service provider performing the verification was chosen based on the use of calibrated equipment and having a national footprint. Nonetheless, this exercise highlights the need for standardisation of audiometric services and also for companies to conduct audits to ensure that the information obtained from service providers is reliable and accurate.

Although audiometric tests were reviewed by occupational health practitioners for individual analysis in all the eight companies, this analysis focused on detection of compensable disease rather than early identification of deviation from baseline testing.

Most of the recommendations in the NIHL Regulations stipulate what employers should do at a programme level, but applying these interventions or programmes at an individual level requires, among other resources, clinical administrative capacity. It was noted that the participating companies followed different practices regarding documentation and collation of information to be used for each individual, in line with the individual's clinical assessment.

Cross-sectional studies are likely to underestimate NIHL due to the "healthy worker effect". Consequently, company records of NIHL were used in this study to estimate cumulative incidence as well as average annual incidences to determine the extent of NIHL from 2002 to 2012. Cumulative incidence was deemed to be the most appropriate measure to estimate the risk of acquiring occupational NIHL for an

Figure 5. Silencer fitted on a fan exhaust resulted in 11 dB(A) reduction in noise level

individual working in the industry within the last decade. From the calculated cumulative incidence, companies will be able to review various components of the programme, aiming at reducing the incidence of NIHL at a company level over the next 10 years.

Although companies provided training on noise to workers, the short interviews undertaken suggest that the quality of this training could be improved and should be properly evaluated. Practical examination and the issuing of competency certificates may motivate employees to take this training more seriously.

It is important to note that the researchers had access only to medical records from company employees. No data were available for contracted employees and therefore the incidence of hearing loss, together with other relevant medical surveillance information relating to contracted employees, could not be reported.

CONCLUSION

The aim of this study was to evaluate noise and hearing conservation practices within eight major producers of iron and steel in South Africa.

The study highlighted that, although these companies had hearing conservation programmes in place, there were shortcomings in the implementation of some elements of the programmes, in particular with regard to worker's training and audiometric testing. Reducing the overwhelming reliance on hearing protection by incorporating additional engineering control strategies is often a difficult task but could go a long way to preventing NIHL.

It is important that all stake holders in the programme (medical practitioners, occupational hygienists, health and safety personnel, management and workers) communicate regularly about hearing conservation issues in order to make well-informed decisions and develop workable solutions to problems. It is also important that companies monitor and continuously evaluate the efficacy of their HCP. This should be done at a company level, but also at an industry level, in the form of peer evaluation where companies are provided the opportunity to share and discuss examples of good practices that can result in positive outcomes in terms of NIHL. The DoL could play an important role in promoting and facilitating such discussions, which could also lead to improvements at a regulatory level.

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LESSONS LEARNED

1. The noise and hearing conservation training provided to workers did not always translate to higher levels of awareness and competency.
2. Audiometric tests conducted by companies could not, in many instances, be reproduced by a third-party service provider.
3. The analysis of audiograms by health practitioners tends to focus on detection of compensable disease, while early intervention, before the compensable 10 PLH occurs, may prevent further deterioration in hearing.

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