

Occupational Noise Exposure and its effects on hearing among Hospital Support Workers at Jigme Dorji Wangchuck National Referral Hospital, Thimphu, Bhutan: A Cross-Sectional Study

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ABSTRACT

Background: Occupational noise-induced hearing loss (NIHL) is well documented in mining and manufacturing but remains largely understudied in hospital settings. Support workers in laundry units, oxygen plants, and Central Sterile Supply Departments (CSSDs) face routine exposure to hazardous noise yet are underrepresented in hearing conservation research.

Objective: To evaluate occupational noise exposure and its audiological impact among support workers in three high-noise departments at Jigme Dorji Wangchuck National Referral Hospital (JDWNRH), Bhutan. **Methods:** This cross-sectional study enrolled all 49 support workers across the oxygen plant, laundry unit, and CSSD at JDWNRH. Data were collected using structured questionnaires, calibrated noise dosimetry, and pure-tone audiometry performed by a certified audiologist. Both air and bone conduction thresholds were measured at 250, 500, 1000, 2000, 4000, and 8000 Hz. Occupational NIHL (ONIH) was defined by a sensorineural notch at 4 kHz with partial recovery at 8 kHz. Data were analyzed using descriptive statistics and chi-squared tests, with significance set at $p < 0.05$. **Results:** ONIH prevalence was high across all departments: oxygen plant (85.7%), laundry unit (85.0%), and CSSD (73.3%). Severity was positively associated with exposure duration; however, early audiometric changes were observed even among younger, less-tenured workers. Hearing protection use was low across all departments, particularly in CSSD (6.6%) and the oxygen plant (7.1%). Men demonstrated higher rates of mild-to-moderate hearing loss, while workers aged 40–49 years exhibited the highest prevalence of moderate-to-severe impairment. **Conclusion:** These findings expose a serious, previously unaddressed occupational hearing health gap at JDWNRH. The high prevalence of ONIH and low adherence to hearing protection demonstrate the need for engineering controls, administrative safeguards, mandatory audiometric surveillance, appropriate hearing protection, and stronger implementation of occupational noise safety measures.

Keywords: Occupational Noise-Induced Hearing Loss (ONIH); Noise Assessment; Personal Protective Equipment (PPE)

INTRODUCTION

Noise-induced hearing loss (NIHL) is a major and escalating global public health concern, affecting approximately 5% of the world's population¹. According to the Global Burden of Disease (GBD) study, an estimated 1.6 billion people live with some degree of hearing loss, with a significant and growing proportion attributable to occupational and environmental noise exposure². The consequences extend beyond audiology; NIHL is associated with decreased workplace productivity, heightened psychosocial stress, communication difficulties, and social isolation, all of which ultimately diminish quality of life^{2,3}.

The pathophysiology of NIHL involves mechanical

and metabolic damage to the cochlear hair cells of the inner ear, particularly the outer hair cells of the organ of Corti. Intense or prolonged noise exposure generates excessive reactive oxygen species and disrupts calcium homeostasis, leading to irreversible hair cell death. This damage characteristically manifests as a sensorineural hearing threshold shift, most pronounced at 3,000–6,000 Hz, with partial recovery at 8,000 Hz, a pattern that distinguishes NIHL from age-related hearing loss. Early stages are often asymptomatic, with affected individuals unaware of progressive cochlear damage until communication difficulties become apparent. Common symptoms include tinnitus, difficulty following conversations in noisy environments, a tendency to increase device volume, and trouble perceiving high-frequency sounds⁴⁻⁸.

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Occupationally, NIHL is most extensively documented in industries such as mining, construction, and manufacturing, where sustained exposure above 85 dB(A) over an 8-hour workday

is well established as hazardous⁹⁻¹¹. Both the World Health Organization (WHO) and the Occupational Safety and Health Administration (OSHA) set this threshold as the permissible exposure limit (PEL), noting that for every 3 dB increase above this level, the safe exposure duration is halved^{12,13}. Despite being entirely preventable through engineering controls, administrative measures, and appropriate hearing protection, NIHL remains a leading cause of occupational morbidity, largely due to persistent underestimation of risk and inconsistent implementation of protective measures^{6,7}.

Although hospitals are not traditionally classified as high-noise environments, growing evidence challenges this assumption. Noise levels in hospital support areas routinely exceed recommended thresholds. Studies from Brazil, Nigeria, and Egypt have documented noise levels ranging from 84 to 101 dB(A) in hospital laundries and sterilization units comparable to industrial settings¹⁴⁻¹⁶. Workers in laundry units, oxygen plants, and Central Sterile Supply Departments (CSSDs) operate industrial-scale machinery, including washers, dryers, autoclaves, ultrasonic cleaners, and oxygen compression equipment, generating sustained high-decibel noise throughout their shifts.

Despite this, hospital support workers remain notably underrepresented in occupational hearing health research and are frequently excluded from institutional hearing conservation programs. Non-occupational factors may also contribute to hearing loss in this population and must be considered when interpreting audiometric findings. These include habitual exposure to recreational loud music, ototoxic medication use, and pre-existing ear pathology—all recognized confounders that can independently or synergistically accelerate hearing threshold deterioration¹⁷⁻¹⁹.

In Bhutan, occupational hearing health remains under-researched, particularly within healthcare settings. A previous study among industrial workers reported NIHL prevalence of 27.9% considerably exceeding the global estimate of 16–24%, suggesting a high-risk occupational landscape²⁰. Bhutan's Occupational Health, Safety, and Welfare Regulation (2022) sets a permissible exposure limit of 85 dB(A) time-weighted average (TWA) over 8 hours, mandating regular noise assessments, annual audiometric testing, PPE provision, and worker education²¹. However, implementation has remained inconsistent, and many hospital workers in high-noise areas continue to work without adequate protection.

At Jigme Dorji Wangchuck National Referral Hospital (JDWNRH), the country's largest 350-bed tertiary care institution, support workers in the oxygen generator plant, CSSD, and laundry unit are routinely exposed to potentially hazardous noise levels. No published data exist on their audiological health. This study therefore aims to assess the prevalence and severity of ONIHL among workers in these three high-noise departments

at JDWNRH, providing the first systematic evidence base of its kind in Bhutan to inform targeted hearing conservation policy.

METHODS

Study Design and Setting

A facility-based cross-sectional study was conducted from March to April 2025 at Jigme Dorji Wangchuck National Referral Hospital (JDWNRH), Thimphu, Bhutan. The study focused on three identified high-noise departments: the oxygen generator plant, Central Sterile Supply Department (CSSD), and laundry unit. These departments were selected based on prior occupational observations at JDWNRH and published evidence indicating elevated noise levels in hospital support areas, particularly CSSD and laundry units.

Study Participant

In this study “hospital workers” refers specifically to non-clinical staff permanently employed in three identified high-noise departments at JDWNRH: the CSSD, the laundry unit, and the oxygen plant. Clinical staff, including nurses and doctors as well as biomedical engineers were not part of the study population.

Inclusion Criteria

To be eligible, participants had to be permanent employed in one of the three designated high-noise departments at JDWNRH (CSSD, laundry unit, or oxygen generator plant) at the time of data collection, with at least 12 months of continuous work in their current departmental role, and to provide written informed consent prior to data collection

Exclusion Criteria

Individuals were excluded if they had a documented history of hearing loss clearly unrelated to occupational noise exposure; current or recent use of known ototoxic medications; a history of major ear surgery or active chronic ear disease (eg, chronic otitis media, otosclerosis); or habitual high-level recreational noise exposure (eg, frequent attendance at loud music venues or daily prolonged use of personal listening devices at high volume), which could confound workplace effects.

The three departments employed a total of 49 workers (CSSD: 15; laundry: 20; oxygen plant: 14). All 49 met the inclusion criteria and none met any exclusion criteria. Accordingly, total population sampling was used, and the final study sample comprised all 49 eligible workers.

Data Collection and Management

Phase 1: Quantitative Questionnaire

Each participant completed a comprehensive structured

questionnaire administered through a face-to-face interview to ensure completeness and quality control. The collected data included socio-demographic details (age, sex, education level), occupational history (work type, employment duration, daily noise exposure, and use of hearing protection devices (HPD)), and overall health conditions. Comorbidities were captured through an open-ended approach during interviews, allowing participants to report any health issues without restriction, including hearing problems and symptoms assessed according to American Speech Language Hearing Association (ASHA) guidelines^{22,23}.

Phase 2: Walk-through Survey and Noise Assessment

At least five site visits were conducted to document work processes, machinery operation, and safety practices, including one unannounced visit to objectively assess hearing protection device usage under routine working conditions. Noise levels were measured by a certified professional using a pre- and post-calibrated sound level meter, with 15-minute grab samples recorded at each workstation. Measurements were compared against the national permissible exposure limit of 85 dB(A) time-weighted average (TWA) over 8 hours as prescribed by Bhutan's Occupational Health, Safety and Welfare Regulation (2022), as well as WHO and OSHA international standards.

Phase 3: Audiometry Test

Hearing assessments were conducted in three sequential steps to ensure diagnostic accuracy and to differentiate NIHL from other causes of hearing impairment:

Step 1: ENT Examination: An ENT specialist conducted initial clinical examinations for all participants to rule out alternative causes of hearing loss, including chronic otitis media, otosclerosis, and other structural ear pathologies.

Step 2: Pure-Tone Audiometry (PTA): Workers underwent PTA conducted by certified audiologist in a calibrated soundproof booth meeting standard acoustic requirements. Both air and bone conduction thresholds were measured at 250, 500, 1000, 2000, 4000, and 8000 Hz.

Step 3: NIHL Diagnosis: Senior audiologist diagnosed NIHL based on the presence of a bilateral or unilateral sensorineural notch at 4000Hz with partial recovery at 8,000 Hz, consistent with standard audiometric criteria; occupational noise exposure history was used as a supplementary, not standalone, diagnostic factor. Sensorineural hearing loss without this notch pattern was classified separately.

Statistical Analysis

Data were entered and analysed using IBM SPSS Version 22. Descriptive statistics were used to summarize sociodemographic characteristics, occupational profiles, noise exposure levels,

and audiometric outcomes. Chi-squared (χ^2) tests were applied to examine associations between audiometric outcomes and variables including work area, age, sex, and service duration, with a significance level set at $p < 0.05$.

Ethical Consideration

The study activities were conducted in accordance with Ethical guidelines. Ethical approval was obtained from the Research Ethics Board of Health (REBH), Bhutan (Protocol Number: PN/2024/035), granted on March 13, 2025. Written informed consent was obtained from all participants prior to data collection. Participation was voluntary and confidentiality of all data was maintained throughout the study.

RESULT

Sociodemographic Characteristics and Work Description

A total of 49 support workers were enrolled across three departments: oxygen plant ($n = 14$), CSSD ($n = 15$), and laundry unit ($n = 20$). The sociodemographic and occupational characteristics of participants are summarized in Table 1.

Oxygen plant workers were predominantly male (78.5%, $n = 11$), with a mean age of 33.8 years ($SD \pm 5.3$). All oxygen plant workers held secondary-level education and reported no comorbidities. CSSD workers were predominantly female (86.6%, $n = 13$), with an adult age distribution matching a mean profile of 36.8 years ($SD \pm 4.1$). Within the CSSD group, 26.6% ($n = 4$) reported comorbidities including hypertension and diabetes. Laundry unit workers had a more balanced gender distribution (60% female, $n = 12$), with a mean age of 34.7 years ($SD \pm 7.7$), where 35.0% ($n = 7$) reported underlying health metrics.

No participant reported the use of ototoxic medications or a history of ear surgery at the time of the study. Mean work tenure was longest in the oxygen plant (6.1 ± 1.5 years), followed by the laundry unit (5.5 ± 2.3 years) and CSSD (3.4 ± 0.2 years). The majority of workers across all departments reported daily noise exposure durations of 5–8 hours per shift: 100% of oxygen plant workers, 93.3% of CSSD workers, and 95.00% of laundry workers. A minority in CSSD (6.6%) and laundry (5.0%) reported exposure durations of less than 5 hours. These figures reflect actual noise exposure time, which exceeded scheduled shift hours due to overtime and overlapping duties.

Despite daily exposure to hazardous noise levels, hearing protection device (HPD) usage was critically low across all departments: only 7.1% ($n = 1$) of oxygen plant workers, 6.6% ($n = 1$) of CSSD workers, and 40.0% ($n = 8$) of laundry unit workers reported using HPDs under routine schedules. The majority of workers reported never having attended a noise-related awareness or hearing conservation program

Walk-through survey and noise assessment in the study site.**a) Work Process Documentation**

At least five visits were conducted to each department to observe and document work processes, machinery operation patterns, workflow organization, and existing safety practices. One visit was conducted unannounced to objectively assess real-world hearing protection device usage under routine working conditions. All workers in the three departments followed rotating shifts alternating between morning (8:00 AM–2:00 PM) and afternoon (2:00 PM–8:00 PM), six days per week. While each scheduled shift lasted six hours, actual noise exposure durations ranged from five to eight hours per shift due to overtime, overlapping duties, and time spent in noisy areas beyond scheduled shift hours.

b) Objective Sound Mapping Measurements

Noise level measurements in the oxygen plant and CSSD consistently exceeded the national permissible exposure limit of 85 dB(A) TWA established by Bhutan's Occupational Health, Safety and Welfare Regulation (2022) and international guidelines, while the laundry unit's washing and spin-drying areas approached but did not exceed this limit at the points measured. Results are broken down by workstation in Table 2.

The oxygen generator plant recorded the highest peak exposure noise level at 101.0 dB(A), followed by the medical gas control room at 93.7 dB(A) and the MCH oxygen generator

plant at 86.5 dB(A) -all three exceeding the national limit. Within the CSSD workspace, the autoclave operational room measured a severe 96.4 dB(A), well above the limit, while the common break area recorded a safe 61.9 dB(A). In the laundry unit, both the industrial washing and spin-drying areas recorded 84.5 dB(A)-just under the 85 dB(A) threshold-while quieter workflow segments included the manual folding area (54.3 dB(A)) and the enclosed rest area (58.0 dB(A)).

c) Prevalence of Self-Reported Auditory Symptoms

Self-reported auditory symptoms among workers are indexed in Table 3. Across all three departments, a high proportion of workers reported symptoms consistent with noise-induced auditory impairment. In the laundry unit, 15.0% of workers reported outside-work complaints regarding high television volume, while 60.0% reported difficulty understanding conversations in noisy social environments while at work. Over 50.0% of workers across all departments reported frequently misunderstanding others or requiring repetition during conversations. Tinnitus-related symptoms, including dizziness, ear pain, or ringing in the ears, were reported by 40.0% of laundry workers, 50.0% of oxygen plant workers, and 46.7% of CSSD workers.

Phase 3: Pure-Tone Audiometric Evaluation

The overall prevalence of ONIHL, defined as structural hearing loss in at least one ear meeting the strict diagnostic criteria of

Table 1. Sociodemographic and Occupational Characteristics of Workers by Department at the National Referral Hospital, Bhutan, 2025 (n = 49)

Variable	Characteristics	Oxygen Plant (n=14)	CSSD (n=15)	Laundry Unit (n=20)
Mean Age ± SD	In years	33.8 ± 5.3	36.8 ± 4.1	34.7 ± 7.7
Gender, n (%)	Male	11 (78.5)	2 (13.3)	8 (40.0)
	Female	3 (21.4)	13 (86.6)	12 (60.0)
Education, n (%)	Tertiary Level	0 (0.0)	1 (6.6)	1 (5.0)
	Secondary Level	14 (100.0)	14 (93.3)	10 (50.0)
	Primary Level	0 (0.0)	0 (0.0)	2 (10.0)
	Illiterate	0 (0.0)	0 (0.0)	7 (35.0)
Smoking Status, n (%)	Yes	1 (7.1)	0 (0.0)	5 (25.0)
	No	13 (92.8)	15 (100.0)	15 (75.0)
Comorbidities, n (%)	Yes	0 (0.0)	4 (26.6)	7 (35.0)
	No	14 (100.0)	11 (73.3)	13 (65.0)
Mean Service Tenure	Years ± SD	6.1 ± 1.5	3.4 ± 0.2	5.5 ± 2.3
Daily Exposure, n (%)	< 5 hours	0 (0.0)	1 (6.6)	1 (5.0)
	5–8 hours	14 (100.0)	14 (93.3)	19 (95.0)
HPD Usage, n (%)	Yes	1 (7.1)	1 (6.6)	8 (40.0)
	No	13 (92.8)	14 (93.3)	12 (60.0)

Table 2: Noise Levels by Workstation and Compliance with National Limit

Location	Workstation	Leq dB(A)	Exceeds National 85 dB(A) Limit
Oxygen Plant	Office	67.0	No
Oxygen Plant	Medical gas control room	93.7	Yes
Oxygen Plant	Oxygen generator plant	101	Yes
Oxygen Plant	MCH oxygen generator plant	86.5	Yes
Oxygen Plant	Footpath near oxygen plant	78.0	No
CSSD Unit	Common area	61.9	No
CSSD Unit	Autoclave room	96.4	Yes
Laundry Unit	Washing area	84.5	Near/Exceeds Limit
Laundry Unit	Spin drying area	84.5	Near/Exceeds Limit
Laundry Unit	Folding area	54.3	No
Laundry Unit	Rest area	58.0	No

Leq = Equivalent continuous sound level; CSSD = Central Sterile Supply Department; MCH = Maternal and Child Health. The national permissible exposure limit is 85 dB(A). Values of 84.5 dB(A) are flagged as “Near/Exceeds Limit” as they approach the threshold.

Table 3: Hearing Difficulty Symptoms Across Work Units (n = 49)

Symptom	Oxygen Plant (n=14)		CSSD (n=15)		Laundry Unit (n=20)	
	Outside Work	At Work	Outside Work	At Work	Outside Work	At Work
Telephone Difficulty	1 (7.1)	8 (57.1)	5 (33.3)	5 (33.3)	5 (25.0)	11 (55.0)
Group Conversation Issues	1 (7.1)	1 (7.1)	1 (6.7)	15 (100.0)	3 (15.0)	13 (65.0)
High TV Volume Complaints	0 (0.0)	0 (0.0)	1 (6.7)	1 (6.7)	3 (15.0)	N/A
Straining to Understand	0 (0.0)	8 (57.1)	2 (13.3)	2 (13.3)	5 (25.0)	12 (60.0)
Noisy Background Trouble	9 (64.3)	14 (100.0)	9 (60.0)	9 (60.0)	7 (35.0)	12 (60.0)
Tinnitus / Ear Pain / Ringing	0 (0.0)	14 (100.0)	9 (60.0)	5 (33.3)	8 (40.0)	8 (40.0)
Inappropriate Responses	1 (7.1)	0 (0.0)	7 (46.6)	1 (6.7)	4 (20.0)	12 (60.0)
Missing Parts of Conversation	0 (0.0)	5 (35.7)	0 (0.0)	1 (6.7)	3 (15.0)	12 (60.0)
Concentration Disorders	0 (0.0)	0 (0.0)	0 (0.0)	2 (13.3)	1 (5.0)	4 (20.0)

Values presented as n (%).

a sensorineural notch at 3,000–6,000 Hz with partial recovery at 8,000 Hz, was high across all three departments. Results are presented in Table 4.

ONIHL was present in 85.7% (n = 12) of oxygen plant workers, 85.0% (n = 17) of laundry unit workers, and 73.3% (n = 11) of CSSD workers. Bilateral ONIHL was most prevalent in the oxygen plant (42.86%, n = 6), indicating widespread hearing loss affecting both ears. In contrast, bilateral ONIHL was least prevalent in the CSSD (26.7%, n = 4). Right ear involvement was most common in the laundry unit (70.0%, n = 14) and oxygen

plant (64.3%, n = 9).

The clinical distribution of ONIHL severity stratified across demographics, work classification parameters, and total years of continuous exposure service is organized in Table 5. Male workers demonstrated a higher prevalence of mild-to-moderate hearing loss compared to female workers across all three departments. In the oxygen plant, 63.0% of male workers presented with mild hearing loss in the right ear.

Workers aged 40–49 years bore the greatest baseline burden of moderate-to-severe hearing impairment across departments. In the laundry unit, 50.0% of workers in this

Table 4: Prevalence and Laterality of Occupational Noise-Induced Hearing Loss (ONIHL) Among Hospital Support Workers (n= 49)

Unit Department	Total Screened (N)	ONIHL Present n (%) [*]	Normal Hearing n (%)	Bilateral ONIHL n (%) ^{**}	Right Ear ONIHL n (%) ^{***}	Left Ear ONIHL n (%) ^{***}
Oxygen Gas Plant	14	12 (85.7)	2 (14.3)	6 (42.9)	9 (64.3)	7 (50.0)
CSSD	15	11 (73.3)	4 (26.7)	4 (26.7)	5 (33.3)	6 (40.0)
Laundry Unit	20	17 (85.0)	3 (15.0)	6 (30.0)	14 (70.0)	9 (45.0)
Total Cohort	49	40 (81.6)	9 (18.4)	16 (32.7)	28 (57.1)	22 (44.9)

^{*} “Present” refers to the diagnostic confirmation of an occupational noise-induced sensorineural notch in at least one ear (unilateral or bilateral).

^{**} “Bilateral ONIHL” indicates that the criteria for a noise notch were met in both ears simultaneously.

^{***} The sum of individual right and left ear columns exceeds the total number of affected individuals because bilateral cases are accounted for in both columns to demonstrate precise ear-specific laterality.

age group demonstrated moderate-severe hearing loss in the right ear, while the left ear in this same subgroup showed only minimal hearing loss-indicating a right-ear-predominant pattern rather than bilateral severe involvement. Workers in the 20–29 age group also showed early audiometric changes, indicating hearing threshold shifts even at younger ages and shorter service durations. Unlike the laundry and oxygen plant units, CSSD-affected workers showed exclusively minimal-to-mild severity on audiometry, with no moderate or moderate-to-severe cases recorded in any subgroup-despite a still-substantial overall ONIHL prevalence of 73.3% in that department. In the laundry unit, workers with 5–8 years of service showed higher rates of moderate hearing loss (42.8% right ear) compared to those with less than 5 years of service (33.3% right ear).

The inferential cross-tabulation analyses measuring the specific structural associations between occupational lifestyle metrics and overall ONIHL prevalence are detailed in Table 6.

In the laundry unit, a statistically significant association was established between work duration exceeding 5 years and absolute ONIHL development ($\chi^2 = 4.22$, $p = 0.04$), establishing cumulative occupational timeline limits as a severe risk factor within that department. Within the CSSD and oxygen plant cohorts, direct categorical tracking profiles did not cross the strict mathematical significance thresholds due to smaller localized sample cell limitations. No statistically significant associations were found between gender and ONIHL (laundry: $p = 0.12$; CSSD: $p = 0.15$; oxygen plant: $p = 0.67$) or between general age groupings across baseline environments.

DISCUSSION

This study investigated occupational noise exposure and its audiological consequences among hospital support workers at

JDWNRH, representing the first systematic investigation of its kind conducted in Bhutan. The findings reveal a serious and largely unaddressed occupational health burden, with ONIHL prevalence exceeding 70% across all three departments studied.

Noise measurements across all three departments consistently exceeded the national permissible exposure limit of 85 dB(A) TWA established by Bhutan’s Occupational Health, Safety and Welfare Regulation (2022) and WHO/OSHA international standards. The oxygen generator plant recorded the highest level at 101 dB(A), followed by the CSSD autoclave room at 96.4 dB(A) and the laundry washing area at 84.5 dB(A). At 101 dB(A), safe unprotected exposure time is reduced to less than 30 minutes per day, yet workers in this unit reported daily exposure durations of 5–8 hours. These findings are consistent with studies from Brazil, Nigeria, and Egypt, where hospital laundry and sterilization units similarly recorded noise levels between 84 and 101 dB(A), confirming that hospital support environments carry industrial-level acoustic hazards comparable to mining and construction settings ^{8, 14-16}.

ONIHL prevalence was markedly elevated across all departments: 85.7% in the oxygen plant, 85.0% in the laundry unit, and 73.3% in the CSSD. These figures substantially exceed the global occupational NIHL prevalence estimates of 16–24% and are considerably higher than the 27.9% previously reported among industrial workers in Bhutan²⁰. They are, however, consistent with a study among 239 healthcare workers that reported an overall NIHL prevalence of 38.5%, and with international evidence demonstrating that up to 44% of noise-exposed workers develop NIHL after 4.5–5 years of exposure²⁴⁻³². The notably higher prevalence observed in this study may reflect the combination of high ambient noise levels, prolonged daily exposure durations, and critically low hearing protection

Table 5: Hearing Loss Severity by Ear, Department, and Subgroup

Department / Sub-group	Right Ear, n (%)				Left Ear, n (%)			
	Minimal	Mild	Mod	Mod-Sev	Minimal	Mild	Mod	Mod-Sev
LAUNDRY UNIT (n=20)								
Female (n=12)	0 (0.0)	0 (0.0)	2 (16.6)	1 (8.3)	4 (33.3)	1 (8.3)	0 (0.0)	0 (0.0)
Male (n=8)	0 (0.0)	0 (0.0)	3 (37.5)	2 (25.0)	0 (0.0)	3 (37.5)	0 (0.0)	0 (0.0)
Age: 20–29 Years (n=7)	0 (0.0)	0 (0.0)	2 (28.5)	2 (28.5)	1 (14.2)	2 (28.5)	0 (0.0)	0 (0.0)
Age: 30–39 Years (n=9)	0 (0.0)	0 (0.0)	3 (33.3)	1 (11.1)	2 (22.2)	1 (11.1)	0 (0.0)	0 (0.0)
Age: 40–49 Years (n=4)	0 (0.0)	0 (0.0)	0 (0.0)	2 (50.0)	2 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)
Tenure: < 5 years (n=12)	0 (0.0)	0 (0.0)	4 (33.3)	1 (8.3)	2 (16.6)	3 (25.0)	0 (0.0)	0 (0.0)
Tenure: 5–8 years (n=7)	0 (0.0)	0 (0.0)	2 (33.3)	2 (28.5)	3 (42.8)	0 (0.0)	0 (0.0)	0 (0.0)
Tenure: > 8 years (n=1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
CSSD UNIT (n=15)								
Female (n=13)	1 (7.7)	3 (23.1)	0 (0.0)	0 (0.0)	2 (15.4)	4 (30.8)	0 (0.0)	0 (0.0)
Male (n=2)	0 (0.0)	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Age: 20–29 Years (n=1)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
Age: 30–39 Years (n=10)	0 (0.0)	3 (28.6)	0 (0.0)	0 (0.0)	1 (14.3)	3 (28.6)	0 (0.0)	0 (0.0)
Age: 40–49 Years (n=4)	0 (0.0)	1 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (50.0)	0 (0.0)	0 (0.0)
Tenure: < 5 years (n=13)	1 (7.7)	3 (23.1)	0 (0.0)	0 (0.0)	2 (15.4)	2 (15.4)	0 (0.0)	0 (0.0)
Tenure: 5–8 years (n=2)	0 (0.0)	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)	0 (0.0)	0 (0.0)
Tenure: > 8 years (n=0)	—	—	—	—	—	—	—	—
OXYGEN PLANT (n=14)								
Female (n=3)	0 (0.0)	2 (66.6)	0 (0.0)	0 (0.0)	0 (0.0)	2 (66.6)	0 (0.0)	0 (0.0)
Male (n=11)	0 (0.0)	7 (63.6)	0 (0.0)	0 (0.0)	0 (0.0)	3 (27.2)	0 (0.0)	2 (18.1)
Age: 20–29 Years (n=4)	0 (0.0)	2 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (50.0)	0 (0.0)	1 (25.0)
Age: 30–39 Years (n=10)	0 (0.0)	8 (77.7)	0 (0.0)	0 (0.0)	0 (0.0)	3 (33.3)	0 (0.0)	1 (11.1)
Age: 40–49 Years (n=0)	—	—	—	—	—	—	—	—
Tenure: < 5 years (n=9)	0 (0.0)	5 (55.5)	0 (0.0)	0 (0.0)	0 (0.0)	3 (33.3)	0 (0.0)	2 (22.2)
Tenure: 5–8 years (n=0)	—	—	—	—	—	—	—	—
Tenure: > 8 years (n=5)	0 (0.0)	4 (80.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (40.0)	0 (0.0)	0 (0.0)

Mod = Moderate hearing loss; Mod-Sev = Moderately-severe hearing loss; CSSD = Central Sterile Supply Department.

Values are n (%) of workers in each subgroup falling into each hearing-loss severity category, by ear

usage, factors that together create conditions for accelerated and cumulative cochlear damage.

A particularly concerning finding was the detection of early audiometric changes among younger workers and those with shorter service durations. Workers in the 20–29 age group demonstrated measurable hearing threshold shifts, indicating that cochlear damage begins well before clinical symptoms become apparent. This is consistent with established evidence that significant hearing threshold shifts can occur after as little as 4.5 years of unprotected noise exposure^{24–28}. The 40–49 age group bore the greatest burden of moderate-to-severe impairment, reflecting the cumulative and irreversible nature of noise-induced cochlear damage over time. These findings underscore the critical importance of early audiometric surveillance, particularly for workers in the first years of employment in high-noise departments.

Despite daily exposure to noise levels substantially exceeding safe thresholds, HPD usage was critically low: 7.14% in the oxygen plant, 6.67% in the CSSD, and 40% in the laundry unit. Furthermore, the majority of workers reported never having attended a noise-related awareness or hearing conservation program. These findings reflect a pattern consistently documented across occupational settings globally: low PPE adherence driven by inadequate awareness, poor availability of appropriate devices, discomfort during use, and absence of institutional enforcement^{33, 34}. The particularly low usage in the oxygen plant and CSSD is especially concerning given that these departments recorded the highest noise levels. The collaboration with the Korea SHE Foundation, which provided earplugs and conducted awareness workshops, represents a valuable initial intervention; however, a single-point donation is insufficient without sustained institutional commitment to hearing conservation.

Table 6: Association Between Worker Characteristics and ONIHL, by Department

Category	Laundry Unit			CSSD			Oxygen Plant		
	Subgroup	ONIHL Present, n (%)	p-value	Subgroup	ONIHL Present, n (%)	p-value	Subgroup	ONIHL Present, n (%)	p-value
Work Role Type	Collection (n=11)	10 (90.9)	0.320	Operator (n=13)	10 (76.9)	0.360	Supervision (n=11)	9 (81.8)	0.330
	Laundry (n=7)	6 (85.7)		Cleaner (n=1)	0 (0.0)		Monitoring (n=3)	3 (100.0)	
	Management (n=2)	1 (50.0)		Manager (n=1)	1 (100.0)			0	
Service Years	< 5 Years (n=12)	11 (91.6)	0.040	< 5 Years (n=13)	9 (69.2)	0.100	< 5 Years (n=9)	7 (77.8)	0.540
	5–8 Years (n=7)	6 (85.7)		5–8 Years (n=2)	2 (100.0)		5–8 Years (n=0)	0	
	> 8 Years (n=1)	0 (0.0)		> 8 Years (n=0)	0		> 8 Years (n=5)	5 (100.0)	
Age Profile	20–29 Years (n=7)	6 (85.7)	0.580	20–29 Years (n=1)	1 (100.0)	0.390	20–29 Years (n=4)	3 (75.0)	0.250
	30–39 Years (n=9)	7 (77.7)		30–39 Years (n=10)	7 (70.0)		30–39 Years (n=10)	9 (90.0)	
	40–49 Years (n=4)	4 (100.0)		40–49 Years (n=4)	3 (75.0)		40–49 Years (n=0)	0	
Gender Distribution	Female (n=12)	9 (75.0)	0.120	Female (n=13)	10 (76.9)	0.150	Female (n=3)	2 (66.7)	0.670
	Male (n=8)	8 (100.0)		Male (n=2)	1 (50.0)		Male (n=11)	10 (90.9)	

ONIHL = Occupational Noise-Induced Hearing Loss; CSSD = Central Sterile Supply Department.

Values are n (%) of workers in each subgroup with ONIHL present. The p-value is a single omnibus association test (chi-squared / Fisher's exact, as appropriate) comparing ONIHL prevalence across all subgroups listed within that category, for that department, and is reported once per category-department combination rather than as a pairwise comparison.

Male workers demonstrated higher rates of mild-to-moderate hearing loss compared to female workers across departments. This finding may reflect differences in job roles, as male workers in the oxygen plant predominantly occupied operational positions involving direct machinery contact, as well as potentially higher non-occupational noise exposure among males. These findings are consistent with broader occupational health literature linking male sex to higher NIHL prevalence in industrial settings.

Limitations of the Study

Several methodological limitations must be considered when interpreting these findings. First, due to the cross-sectional design of this study, data were captured at a single point in time, preventing the establishment of direct causal relationships or the chronological tracing of threshold trajectories over time. Second, while non-occupational confounders-including recreational noise exposure, ototoxic medication use, and pre-existing ear

pathology-were meticulously assessed via clinical history questionnaires and baseline ENT examinations, potential recall bias or underreporting of external recreational noise habits could leave residual confounding variables. Third, the small sample size of 49 participants, while representing the entire available support workforce of these three specific departments, limits the absolute statistical power of the chi-squared tests when analyzing minor subgroup variables. Finally, environmental noise assessments were captured using 15-minute grab samples rather than continuous full-shift personal dosimetry, which may overlook acute acoustic fluctuations during peak operating periods.

Recommendations for Institutional Intervention

To mitigate this serious occupational health hazard and achieve rigorous compliance with Bhutan's Occupational Health, Safety and Welfare Regulation (2022), the administration of JDWNRH should implement a multi-tiered Hearing Conservation Program.

First, engineering controls must be prioritized to reduce noise at the structural source. This should include installing custom acoustic enclosures around high-decibel oxygen compression units, fitting heavy-duty vibration-isolation pads under industrial laundry washers or dryers, and applying sound-absorbing baffles to the structural walls of the CSSD autoclave room.

Second, administrative controls should be enacted to modify workflows and limit individual exposure times. Machine operational duties must be systematically reorganized to rotate support staff out of high-noise zones throughout their shifts, and high-visibility signage indicating mandatory hearing protection zones must be permanently posted at all entry doors to the oxygen plant and CSSD autoclave areas.

Third, the hospital needs to institute mandatory, routine audiometric surveillance for all support personnel. The hospital administration should establish a protocol requiring mandatory baseline pure-tone audiometry for all newly hired support staff, followed by mandatory annual audiometric screenings, ensuring that early-onset threshold shifts among younger workers are detected and managed before progressing to permanent impairment.

Finally, the institution must establish a sustained procurement pipeline for high-quality personal protective equipment rather than relying on temporary external donations. The facility must consistently provide comfortable, appropriately rated hearing protection devices, such as earplugs and earmuffs, while simultaneously launching mandatory, recurring training workshops focused on proper device insertion, maintenance, and the long-term health risks of unprotected noise exposure.

CONCLUSION

This study reveals an alarmingly high prevalence of occupational noise-induced hearing loss exceeding 70% among hospital support workers at Jigme Dorji Wangchuck National Referral Hospital. Staff in the oxygen plant, Central Sterile Supply Department, and laundry unit are routinely exposed to hazardous noise levels reaching up to 101 dB(A)—well above the national 85 dB(A) limit—for up to eight hours daily with critically low personal protection usage. The combination of sustained acoustic hazards, minimal protective device compliance, and early-onset threshold shifts among younger workers marks a severe and unaddressed occupational health burden. To preserve long-term hearing health and achieve regulatory compliance with Bhutan's Occupational Health, Safety and Welfare Regulation (2022), the hospital administration must urgently implement a comprehensive hearing conservation program incorporating engineering noise controls, mandatory annual audiometric surveillance, and structured staff safety training.

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Following authors have made substantial contributions to the manuscript as under:

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KY: Concept, design, data collection & review

PW: Concept, design, data collection & review

PD: Concept, design, data collection & review

TD: Concept, design, data collection & review

Authors agree to be accountable for all respects of the work in ensuring that questions related to the accuracy and integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST

None

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