Global Journal of Science Frontier Research: H
Environment & Earth Science
Volume 20 Issue 2 Version 1.0 Year 2020
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Health Impact of Occupational Exposure to Noise - A Mixed Method Assessment

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GJSFR-H Classification: FOR Code: 040699

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Health Impact of Occupational Exposure to Noise – A Mixed Method Assessment

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Methods: A mixed-method approach was adopted to determine the associated health impacts. While the qualitative approach entailed the administration of questionnaires to exposed workers, the quantitative method involved the audiometric assessment of personnel exposed to noise sources at work the flow station and the statistical analysis of questionnaire sad ministered using the Statistical Programme for Social Science (SPSS) version 18.0 SPSS.

Results: Although risk control measures were in place, health surveillance revealed a threshold shift but there was no exceedance of 30 dB (A). Relatedly, there are subjective evidence of Temporary Threshold Shifts (TSS) with symptoms.

Conclusion: Exposure to excessive noise levels remains a potential risk in the oil industry despite the robust risk control measures. Though there might not be presentation of hearing loss, there could be health complaints suggestive of Temporary Threshold Shift (TTS). This exposure could be a precursor to Occupational Noise-Induced Hearing Loss (ONIHL), if exposure to excessive noise levels continues without mitigation.

Keywords: noise, exposure, crude oil, machines, health impact.

I. Background

Exposure to occupational noise is the commonest causation of hearing loss in the United States of America [1]. The majority of industrial machines are operated by personnel and are usually exposed to associated noise for long periods[2]. Prolonged exposure to noise levels higher than 85dB (A), carries the potential risk of causing several health effects such as Noise-Induced Hearing Loss (NIHL). All over the world, exposures of more than 30 million workers to dangerous occupational noise levels at worksites prevails[2]. Noise is one of the most prevalent hazards in most settings with about nine million workers being exposed to time-weighted average (TWA) sound levels of 85 dB (A) and above [3]. In the United States, about 30 million workers are exposed to harmful levels of occupational noise [4].Globally, occupational noise is accountable for 16% of hearing loss in adults [5] which makes noise-induced hearing loss, potentially one of the occupational illnesses in the world. Noise-induced hearing loss (NIHL) is a sensor ineural impairment that affects higher hearing frequencies (3,000 to 6,000 Hz) with an insidious onset after prolonged exposure to noise sources [6]. There are about 4 to 5 million (12-15%) employees in Germany that are exposed to noise levels of 85 dB or above [7]. Noise-induced hearing loss results from overstimulation and damage of the hair cells and their base structures in the inner ear by high noise levels [8]. About 9 million American workers experience exposures to a time-weighted average (TWA) sound level above 85 dBA[8]. Besides age-related hearing loss, noise-induced hearing loss is the second most common sensorineural hearing loss [9].

25% of the oil and gas industry workforce also experience exposures to noise levels above 90 dB on an 8-hour time-weighted average [10]. A routine audiometry test survey on 200 employees working in gas compression stations in India revealed a 6% prevalence rate of noise-induced hearing loss [11]. Prolonged exposure to high-level noise increases hearing threshold shift for higher frequencies and results in hearing loss related symptoms [12]. NIHL is an overlooked illness capable of affecting work safety and performance as well as cause economic losses[13]. In Nigeria, cases of workers' exposures to noise levels above 115 dBA have resulted in a significant increase in hearing threshold levels [14]. The implications of hearing loss are grave in the developing world, where treatment and rehabilitation services, personnel, and awareness are absent or limited [15].Engineering upgrades in the capacity of the study facility were likely to increase noise levels with obvious concern to the workers. Hence, the need to objectively assess the health risks posed by the noise level in the flow station. [16].

The oil industry is a global market with highly sought-after energy products. The world is not ready to have this industry economically liquidated by financial compensations and under-productivity from occupational illnesses, including noise. Considering that noise is a compensable industrial illness, it is imperative that measures be put in place to prevent a negative

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financial impact on the industry [17,18]. The estimated cost of noise to developed countries ranges from 0.2 to 2% of the gross domestic product which may be higher in developing countries[19]. Anecdotal evidence reveals that NIHL will lead to losing highly trained and scarce skilled work force in developing countries to debility. Findings of the present study will contribute to the body of knowledge in managing workers' exposures and formulation of mitigating measures in developing countries. This study thus aimed at exploring noise frequency profile of a typical crude oil flow station, identifying the degree of health effects and present control and remedial measures.

II. Methods

This was adescriptive, cross-sectional study conducted in a crude oil flow station: a water borne production platform anchored to the shore of the Atlantic Ocean in Nigeria. This facility consists of four decks of steel floating in shallow water with the topmost deck used as a Helideck. It houses several units containing several pieces of equipment including three crude-oil separators, generators, a compressor (that provides the pressure to propel crude oil in the pipeline), a metering skid (several meters that measure the volume of crude oil flowing through the facility), sets of valves, an export pipeline, flare stacks (gas flaring unit), an emergency shutdown unit, a surge vessel, a cathodic protector (that protects pipelines from corrosion), a chemical shed, risers (pipelines arising from the sea into the installation), a manifold unit (a network of pipelines), and pump & saver pit (a dumping pit for crude oil spills in the facility). This is anchored to an accommodation barge with 30-bed facility for the crew. The barge facility receives raw crude oil from the surrounding network of subsea well-heads through numerous flow lines and risers to the separators, which separates the crude into crude, gas, and water before pumping out products through an export pipeline to a distant gathering facility.

This facility lies between latitude 4° and 6° north of the equator and longitudes 5° and 9° east [20]. The region where th facility is located consists of 70,000 km^2 of mangrove swamp forest, marshy areas and several pockets of swamps [20].it further consists of several hydrocarbon reservoirs, several oil and gas facilities belonging to several oil multinationals. The study population comprised workers for a single oil firm on the flow station. They included technical staff (electrical, mechanical, operation, instrument, station attendants, reservoir and drilling personnel) and support staff who worked a cycle of two weeks on and two weeks off. The inclusion criterion was personnel working in the noisy areas (pump house, generator building, compressor unit, separator area) of a crude oil flow station for a minimum of 4 hours daily fortnightly.

The sample size of the selected questionnaire respondents in this study consisted of 150 workers of the study population. Collection of both quantitative and qualitative data was done in this study. While the qualitative approach entailed the administration of questionnaires to workers in the oil industry, the quantitative method involved the audiometric assessment of personnel exposed to noise sources in this flow station with statistical analysis of questionnaires using the Statistical Programme for Social Science (SPSS) version 18.0 SPSS. Further qualitative data was collected during a walk-through survey in the facility, which entailed non-participant observation of activities, interaction with medics, operators, etc.

The noise survey was conducted throughout the flow station to identify noisy areas, noise sources and mean values were established. Noise measurements were taken for 30 seconds at each of 30 selected locations, approximately 5meters apart on a grid, with the facility running at 95% of its capacity on the day of the noise survey. Purposive sampling technique was the adopted sampling technique. Frequency band analysis was undertaken at the location with the highest noise level (a Caterpillar generator). The area noise measurements and frequency band analysis were performed using a CEL-485 (serial number 109776), which was calibrated using a CEL-282 calibrator (serial number 3/10921327). CEL is the manufacturer of both the sound level meter and the calibrator based in California, Unites State of America.

The sound level meter consists of a readout display screen, microphone with wind-shield, electronic circuits and touch-screen keyboard. Secondary pre-calibration of the sound level meter was carried out using a calibrator. Primary calibration was carried out in the manufacturer's laboratory, while the secondary calibration was carried out on-site before measurement. The microphone in the meter detected the air pressure variations associated with sound and converted them into electrical signals. These signals were processed by the electronic circuitry of the instrument. The readout displayed the sound level in decibels on the readout screen before the data was stored. During noise measurements, the sound level meter was held at arm's length at the ear height of those exposed. Frequency band analysis was carried out toanalyse the average noise level in the relevant frequency ranges. This allows selection of the appropriate hearing protection methods for the workers.

Interviewer administered questionnaires were designed and pre-tested using close-ended questions. The final questionnaire version was then designed to capture the nature of respondent tasks, health and safety, noise profile of workstation, health status, hobby activities, and noise levels at the workstation. The questionnaires were administered to 150respondents with an accompanying participant information sheet.

A walk-through survey was also conducted in several units to observe activities carried out by personnel that could generate noise as well as other noise sources. The workers were observed for a period of 8 hours in each unit of the installation for noise-generating activities, sources of noise and other significant noise-generating activities in each workstation. Each group and task was identified with their observed job processes. Occasional questions were asked to gain an understanding of processes and explanations. This objective assessment was performed to corroborate the subjective evidence offered by the questionnaire. By normal company policy, a standard written consent form was attached to each of the questionnaires, which were signed by respondents after a detailed explanation of the purpose of the study by the interviewer. Respondents were informed of the voluntary nature of participation. No token or inducement was given to respondents who agreed to take part in the study. Permission for the conduct of the study within the oil installation was sought and obtained from the superintendent of the oil installation.

III. Results

The mean noise level in the core zone of the facility was established to be 86.8 dB (A). The core zone consists of the pump house, generator building, compressor unit and separator area.

a) *Background Characteristics of Respondents*

Age bracket 51-60 years had the highest frequency of 60(40.0%), and the majority of subjects (39.5%) were middle age ranging from 51 – 60 years. Participants with more than eight years of exposure had the highest percentage of 114(76.0%) while for occupation, operations personnel were most frequent with 60(40.0%). About 75% of the subjects had worked in the upstream oil industry for more than eight years. (Table 1).

Table 1: Baseline characteristics of study participants

Age (years)	n(%)
20-30	12(8.0)
31-40	48(32.0)
41-50	30(20.0)
51-60	60(40.0)
Total	150(100.0)
Duration of Exposure (years)	
2-4years	6(4.0)
5-8 years	30(20.0)
More than 8 years	114(76.0)
Total	150(100.0)
Occupation	
Support Personnel	18(12.0)
Electrical Personnel	18(12.0)
Instrumentation Personnel	18(12.0)
Operations Personnel	60(40.0)
Mechanical Personnel	36(24.0)
Total	150(100.0)

b) *Degree of Noise Hazard (Mean of Threshold Frequency Shift)*

The threshold shifts in all the frequencies (0.5 kHz, 1 kHz and 2kHz (Low-Frequency Sum); 1 kHz, 2 kHz& 3 kHz (Speech Sum); 3 kHz, 4 kHz& 6 kHz (High-Frequency Sum)) on both ears were less than 30dB (A) (Table 2).

c) *Noise Threshold range for right and left ear among study participants*

The mean of the threshold shift on both ears ranges from 12.67 dB (A) to 25.67 dB (A). Most subjects in operations and mechanical discipline reported difficulty in hearing (Table 3).

d) *Frequency of Reported Health Effects of Exposure to Noise*

All the subjects reported varying percentages of health effects except hearing loss. None of the subjects reported hearing loss. Annoyance and Headache both had the highest percentage occurrence 84(56.0%) while the least was sleep disturbance(4.0%) and irritability (4.0%)(Table 4).

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Table 2: Degree of Noise Hazard (Mean of Threshold Frequency Shift)

Frequencies	Mean Ranges dB (A)	Remarks
Right Ear Frequencies: 0.5kHzkHz,1kHz& 2kHz (Low-Frequency Sum)	12.67 - 23.67	No mean exceedance above 30 dB (A)
Left Ear Frequencies: 0.5kHz,1kHz& 2kHz (Low-Frequency Sum)	13.67 - 23.00	No mean exceedance above 30 dB (A)
Right Ear Frequencies: 1 kHz,2 kHz& 3 kHz (Speech Sum)	16.00 - 25.00	No mean exceedance above 30 dB (A)
Left Ear Frequencies: 1 kHz,2 kHz& 3 kHz (Speech Sum)	15.00 - 23.67	No mean exceedance above 30 dB (A)
Right Ear Frequencies: 3 kHz,4 kHz& 6 kHz (High-Frequency Sum)	18.00 - 25.67	No mean exceedance above 30 dB (A)
Left Ear Frequencies: 3 kHz,4 kHz& 6 kHz (High-Frequency Sum)	18.00 - 24.33	No mean exceedance above 30 dB (A)

Table 3: Noise Threshold range for right and left ear among study participants

Frequencies	Ranges dB (A)
Right Ear	
Right ear 0.5kHz	10.00 - 22.00
Right ear 1 kHz	10.00 – 24.00
Right ear 2 kHz	16.00 – 25.00
Right ear 3 kHz	16.00 – 26.00
Right ear 4 kHz	18.00 – 25.00
Right ear 6 kHz	18.00 – 26.00
Left Ear	
Left ear 0.5kHz	14.00 – 26.00
Left ear 1kHz	10.00 – 25.00
Left ear 2kHz	15.00 – 25.00
Left ear 3 kHz	15.00 – 25.00
Left ear 4 kHz	15.00 – 25.00
Left ear 6kHz	16.00 – 28.00

Table 4: Frequency of Reported Health Effects of Exposure to Noise

Variables (Symptoms)	Frequency			Percentage (%)	
	Yes	No	Total	Yes	No
Tinnitus	66	84	150	44.0	56.0
Annoyance	84	66	150	56.0	44.0
Headache	84	66	150	56.0	44.0
Hearing Loss	0	150	150	0	100.0
Difficulty in Hearing	48	102	150	32.0	68.0
Sleep Disturbance	6	144	150	4.0	96.0
Irritability	6	144	150	4.0	96.0
Tense Feeling	42	108	150	28.0	72.0

IV. Discussion

Exposure to occupational noise sources potentially causes transient physiological outcomes which include increased heart rate, blood pressure, peripheral vasoconstriction and thus increased peripheral vascular resistance [17]. Several occupational studies have suggested that workers exposed to continuous noise for a prolonged period at 85 dB have a higher blood pressure compared to those not exposed to noise; however, this is a transient physiological occurrence [17]. All the subjects confirmed the existence of risk control programs [21] as evidenced by their training and information on the Hearing Conservation Programme, availability of hearing protection signage, plant maintenance schedule, annual noise assessment and personnel compliance with the use of recommended hearing defenders (Ear-Muffs and

Ear-plugs). However, personnel who have spent more than eight years working in the oil and gas industry commonly reported tinnitus, annoyance, headache and difficulty in hearing (hard of hearing). This raises concerns about the compliance of personnel with control measures where confirmed as being available. For most of the findings, the magnitude of the differences was small. Few significant relationships were found between small threshold shifts and markers of exposure and symptoms. This statistical relationship is consistent with literature on noise-induced hearing loss in which threshold shifts of less than 30 dB (A) are not usually associated with hearing loss. Though the threshold shift does not qualify for a classical definition of hearing loss (Permanent Threshold Shift-Permanent Threshold Shift) due to the non-exceedance of 30dB (A); it rightly situated a case of temporary threshold shift (TTS) [22]. Moreover, the presence of transient signs and symptoms such as tinnitus, headache, sleep disturbance, difficulty in hearing (temporary hard of hearing), and annoyance are suggestive of exposure to noise and occurrence of temporary threshold shift.

The presence of risk control measures as enshrined in the Hearing Conservation Programme is a testament to the high level of health risk management in Oil and Gas Companies; however, the effectiveness of these measures remains a subject to be investigated in further studies. Risk management measures should be able to manage health risks at ALARP (As Low As Reasonably Practicable). Managing risk exposure to noise in the oil industry be hooves both the employer and employee to synergize their responsibilities toward achieving this objective [11]. The risks should be assessed to include identification of noise hazards, estimate the probable exposure to noise sources, identify SMART (Specific, Measurable, Achievable, Realistic and Time-Bound) control measures, and document the processes involved. Besides identifying the risks, risk control measures should be deployed to protect employees ensuring that the legal limits are not exceeded. Delineation of hearing protection zone, use of hearing protection, provision of information and training to workers, maintenance of machines and annual health surveillance is a must-do. Though a lot of studies have been done on risk assessment, future work should focus on assessment and review of the mitigation value of risk control measures.

The industrial noise mitigation strategy for already existing facilities should include compliant preventive and corrective maintenance (CM, and PM) schedule; substituting noisy equipment with low noise equipment during turn around maintenance; eliminate machinery with high noise levels above 105 dB (A) during maintenance campaign; use of personal protective equipment selected after attenuation [6, 11]; hazard communication using enlarged noise map, identification and display of ear protection zone (EPZ) sign at the entrance of the facility, awareness training; conduction of annual audiometry for all exposed personnel and long term replacement plan with sound-proof generators [21].Furthermore, there should be the inclusion of noise study outcomes during the design of new facilities, a policy of low noise equipment procurement in future maintenance programs and noise complaint units before the handover of newly constructed facilities.

V. Limitation

There is good internal validity between the results for the right and left ears. However, the occurrence of tinnitus is significantly associated with duration of exposure especially for personnel working at the facility for more than eight years. This could result from inherent bias in the sample occasioned by most of the workers being employed for more than eight years. Further data stratification might give a different result. This is not possible with the data available, but in the future, perhaps the questionnaire could be re-designed to include more categories at older ages.The study did not detect any presentation of hearing loss, though there could be health features suggestive of Temporary Threshold Shift (TTS).

VI. Conclusion

Exposure to excessive noise levels remains a potential risk in the oil industry despite the robust risk control measures. Though there might not be obvious presentation of hearing loss, there could be health features suggestive of Temporary Threshold Shift (TTS). This could be a precursor to Occupational noise-induced Hearing Loss should exposure to excessive noise levels continue without mitigation measures.

Conflict of Interest

The author declares that there is no conflict of interests regarding the publication of this paper.

Author's Contribution

Dr Kennedy A. Osakwe Adakporia designed the study protocol, conducted the field works (noise assessment, secured audiometry consent, audiometry), wrote the manuscript, managed the literature search and managed the statistical analyses of the study.

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