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Impact of Oil Facilities Noise on Workers in a Typical Oil and Gas Industrial Plant

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ABSTRACT: Noise induced hearing loss (NIHL) is becoming a common occupational problem that affects thousands of workers in Nigerian oil and gas industries. NIHL is a serious consequence of exposure to high noise levels (>85dBA). In this study, a comprehensive approach, including noise survey, dosimetry and audiometry, was employed to evaluate noise levels and hearing thresholds of workers in a typical oil and gas industrial plant. The results obtained revealed a direct relationship between noise intensity and hearing loss among workers. Workers whose noise levels were above the Occupational Safety and Health Administration (OSHA) exposure limit of 90dBA were more prone to risk of hearing loss than workers whose noise levels were below the limit. Hearing fit test data further suggest that hearing protection devices (HPDs) and human factors such as physiology and skill in using HPDs, contribute to incidences of hearing loss among workers. Therefore, it is recommended that regular monitoring of workers exposure to noise should be carried out especially when there is a change in facility design or increase in the background noise levels.

Keywords: Noise exposure; Noiseimpact; Oil and gas workers; Oil facilities; Noise survey; Dosimetry; Audiometry; Industrial plant

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I. INTRODUCTION

The increasing operations of the oil industryhave resulted in not only technical and economic progress, but also in an ever-increasing incidence of hearing loss and other noise-related hazards to exposed workers in oil facilities. The Nigerian economy being an oil and gas dependent economy (KPMG Nigeria, 2014) engages thousands of workers who work in oil and gas facilities where noise exposure has been of great concern. Among other potential environmental concerns such as air and water quality, noise attributed to oil and gas operations remains a significant and persistent concern that has proved to be difficult to manage. In Nigeria, the problem is compounded by the seemingly lack of effective legislationsorpoor implementation and enforcement where the legislations exist (Oyedepo and Saadu, 2009). However, some multinational organizations in Nigeria, especially International Oil Companies (IOCs) adopt best practices in their operations by complying with stringent regulations and standards.

Excessive noise is a global occupational health hazard with considerable social and physiological impacts, including elevated blood pressure, reduced performance, sleeping difficulties, annoyance and stress, tinnitus, temporary threshold shiftand noise-induced hearing loss (NIHL) (Palmer et al., 2002; Nelson et al., 2005;Aybek et al., 2010). It is well known that noise can mask both the speech and the alarm sounds. Voice problems such as nodules, loss of voice and abnormalities in the vocal chords can be suffered by the workers that must communicate within noisy environments with levels higher than 85dBA if there is no other way to communicate but the voice (Fernandez et al., 2009). The most significant occupational health effect among the noise-exposed workers is the development of NIHL (Hong, 2005; Nelson et al., 2005). NIHL is a serious consequence of exposure to high noise levels (>85dBA) (Suter, 2002). It has been estimated that one-third of all hearing loss is attributable to noise exposure, and that occupational hearing loss is the most common cause of NIHL (NIH, 1990; Nelson et al., 2005; Feder et al., 2017). In the US, NIHL accounted for approximately 11% of all occupational illnesses (BLS, 2006). In Canada, an estimated one-third of workers, substantially more men than women, had some degree of measured NIHL (Feder et al., 2017). In Britain, it was found that occupational noise exposure (so high that a speaker needed to shout to be heard at arm's length) was responsible for severe hearing difficulties in an estimated 153,000 men and 26,000 women, aged 35 to 64 years (Palmer et al., 2002).Because most NIHL is insidious and chronic in nature, workers usually find it difficult to detect the onset and therefore may be unaware that they are losing their hearing (NIOSH, 2010).Occupational noise exposure and NIHL among oil and gas industry workers has long been recognized as a problem in the developed countries (NIOSH, 1996), yet little is known about the prevalence of NIHL among Nigerian oil and gas industry workers.

The advancement in technology and increasing mechanization in the oil and gas industry accounts for the aggravated noise problems faced in oil and gas facilities today. Since the oil and gas industry is highly mechanized, noise levels in the workplace is likely to be more intense and sustained than any noise levels experienced outside the workplace. This creates a potential for occupational health impact on workers in oil and gas facilities. Typical noise sources in oil and gas industry are compressors, generators, drilling, production pumps, completion activities, truck traffic, etc. Certain conditions such as process upset also result in aggravated noise levels which is usually higher than when the plant is in normal operation mode. The noise generated from these sources have different frequencies, sound pressure levels and durations which makes it very harmful. Therefore, it is important to ascertain the degree of this harm to recommend an effective control measure. Accordingly, this work will assess oil and gas industrial plant workplace noise exposure and compare with existing standards, evaluate the impact of noise exposure on the hearing threshold of workers and determine potential for hearing loss. To the best of our knowledge, this is the first time a comprehensive study involving area noise survey, personal noise dosimetry, audiometric evaluation and hearing fit test is conducted to evaluate the occupational impact of noise in the oil and gas industry in Nigeria.

II. MATERIALS AND METHODS

2.1. Study Area

This study was carried out in a typical oil and gas facility in Delta State of Nigeria. The study was conducted in the plant area where Operators and Technicians are continuously exposed to noise levels at 80dBA and above. The study area is mainly characterized by complex oil and gas operations such as refining, power generation, lifting and rigging, water processing and treatment, transport (air, land and sea), flare system, mechanical equipment such as compressors, vacuum trucks, vibrating machines, public address system and alarms, etc. A preliminary site survey of the plant area was conducted to identify high noise areas above 80dBA and Operators/Technicians who work in those areas.The study area was divided into eight units, namely Air Processing Unit (A10), Thermal Reforming Unit (A20), Catalyst Processing Unit (A30), Intermediate Product Unit (A40), Product Forming Unit (A50), Product Stabilization Unit (A60), Steam Generation Unit (A70) and Product Storage Unit (A80).

2.2. Study Population

The study population consist of Operators and Technicians who work in areas within the plant having noise levels of 80dBA and above. This group of workers, because of the nature of their job spend more time in the plant than in the office. A total of 50 Operators and Technicians were sampled for noise exposure. The sampling method used to determine the sample population was the similar exposure group (SEG) method; a group of workers having the same general exposures for the environmental agents being assessed. Since operations and exposures of workers in a SEG are similar, the exposure profile of any worker within a SEG is representative of other workers in the SEG.

2.3. Methods of Data Collection

Noise exposure monitoring at selected work areas in an oil and gas company in Delta state of Nigeria was conducted for three months. Area noise survey was first conducted using a calibrated Sound Level Meter to screen the entire plant area to identify high noise areas above 80dBA. Personnel dosimetry was subsequently performed on selected Operators and Technicians who work in high noise areas. Audiometry was conducted to generate hearing threshold level data for monitored personnel whose dosimetry results was at 85dBA and above. Personnel were further subjected to Hearing Fit Test to obtain binaural data.

2.3.1. Area Noise Survey

A Quest Technologies 3M 2200 Integrating-Averaging Sound Level Meter (SLM) was used to measure background noise levels in the plant area. The SLM was pre- and post-calibrated using a 3M Quest Technologies QC-10 Calibrator. The SLM measurement settings and specifications are summarized in Table 1. The equivalent continuous A-weighted sound pressure level (Leq) was measured for different reference points by positioning the SLM microphone at a height of 5feet above the ground, while pointing the microphone toward the noise source at approximately 70-90 degrees incident to the noise source.

Table 1:SLM settings and specifications

Parameter	**Setting / Specification**
Exchange Rate	3 dB
Exponential Averaging	Slow
Frequency Weighting	A-Weighting
Measurement Range	50 – 120 dB
Threshold	80 dB

2.3.2. Personnel Dosimetry

Work-shift personal noise dosimetry was conducted to measure the work-shift Leq of all high background noise exposed (HBNE) workers, to account for the potential variability in noise exposure throughout the workday. Quest Technologies 3M Noise Pro Series Personal Noise Dosimeters were used to measure the work-shift Leq. The dosimeters were pre- and post-calibrated using a 3M Quest Technologies QC-10 Calibrator. Dosimeter microphones were clipped to workers' shirts between the collar and shoulder, to capture all sound waves along the ear zone. The dosimeters were clipped to workers' belt or trousers and the excess cord was secured with tape. The workers were instructed not to blow on, yell into, or intentionally bump the microphone during sampling. Work-shift Leq measurements were collected and recorded for workers on the same day that background noise levels of workers were measured. The dosimeters measurement settings and specifications used are summarized in Table 2.

Table 2: Dosimeters settings and specifications

Parameter	Setting / Specification
Exchange Rate	3 dB
Response	Slow
Frequency Weighting	A-Weighting
Measurement Range	40 – 140 dB
Threshold	80 dB

2.3.3. Audiometry

Personnel within the sample population who are exposed to noise levels at or above 85dBA were subjected to pure tone audiometry to test for threshold shifts that constitute a departure from their individual pre-employment baseline.Monaural hearing impairment was evaluated for each personnel by determining hearing threshold levels for each ear at test frequencies of 500, 1,000, 2,000, 3,000, 4,000, 6,000 and 8,000 Hz. The average of the sum of these threshold levels were taken and compared to a threshold limit of 25dB. If the average of these hearing levels is 25 dB or less, no impairment was considered to exist in the ability to hear daily sounds under everyday listening conditions.Two audiograms were used during this research, namely baseline and annual audiograms. The baseline audiogram is the reference audiogram against which subsequent audiograms are compared. Baseline audiograms must be provided within six months of an employee's first exposure at or above a Time Weighted Average (TWA) of 85 dBA. Potentially overexposed personnel within the sample population were all scheduled for annual audiograms which were conducted during this study and results compared to baseline audiograms to determine whether the audiogram is accurate and whether any tested employee has lost hearing ability; that is, to determine whether a standard threshold shift (STS) has occurred.

2.3.4. Hearing Fit Test

The Hearing Fit Test machine was setup following the manufacturer's guide. Each employee was invited to sit on a chair in front of the speaker after which the Fit Test process was explained to the employee. The employee'ssound pressure level in dBA was entered into the setup system. The Fit Test machine was calibrated using 105 dBA which is the maximum noise level in the plant. The employee selected from a range of electronic Hearing Protection Devices (HPDs) available based on what he or she uses in the plant. The selected electronic HPD was donned by the employee. With the employee properly positioned, the 'Run Test' button was clicked. A short signal was heard from the loudspeaker, followed by a display of the employee's test result showing: Personal Attenuation Rating (PAR), the date and time tested, and if it passed or failed.

2.3.5. Calibrating Noise Monitoring Instruments

Noise dosimeters and the SLM were calibrated before and after use (pre-and post-calibration), using 3M acoustic calibrator. The device's microphone was placed in a cavity where it is subjected to a known sound level (114 dB) at a fixed frequency (1000 Hz). The calibrate button was then pressed to calibrate the instrument. The dosimeters and SLM all passed pre-calibration by measuring sound level of 114 dBA. This process was repeated to post-calibrate the instruments after use.

2.4. Methods of Data Analysis

Basic descriptive statistics and suitable mathematical descriptors such as MS Excel, Noise calculator software and OSHA Noise Dose Calculator were used in analyzing the data obtained. Percentage Noise Dose (PND) was calculated using Equation (1):

$$PND = 100\left[\frac{t_1}{T_1} + \frac{t_2}{T_2} + \ldots + \frac{t_n}{T_n}\right] \qquad (1)$$

wheret= Actual time exposed at each dB level, and T = Time allowed to be exposed at each dB level. T was obtained from Tables 3 and 4. It was also calculated using Equation (2):

$$T = \frac{8}{2^{(L-90)/5}} \qquad (2)$$

where L = Sound pressure level in dB.

Table 3: OSHA permissible exposure levels (PEL)

Exposure Time (Hours)	PEL (dBA)
No time limit	<90
8	90
4	95

2	100
1	105
0.5	110

OSHA PEL (1971 – Present)

Table 4: Hearing Conservation Amendment (HCA)

Exposure Time (Hours)	PEL (dBA)
32	80
16	85
8	90
4	95
2	100
1	105
0.5	110

OSHA Occupational Noise Regulations – 1910.95 (1981-1983)

Average values of sound pressure levels were computed using Equation (3):

$$L_a = 20\log_{10}\frac{1}{n}\sum_{i=1}^{n}10^{L_i/20} \qquad (3)$$

where L_a = Average sound pressure level in dB, N = Number of readings, L_i = ith sound pressure level in dB, and i = 1, 2, 3, ...n

Equivalent continuous sound pressure level(Leq) which would have same total acoustic level as the real fluctuating noise over the same period was calculated using Equation (4):

$$L_{eq} = 10\log_{10}\left[\frac{1}{T}\sum_{i=1}^{n}10^{0.1L_i}t_i\right] \qquad (4)$$

where T = Time period over which L_{eq} is determined, n = Number of samples, and t_i = Fraction of the total time.

Noise pollution level (NPL) was calculated using Equation (5):

$$NPL = L_{50} + (L_{10} - L_{90}) + \frac{(L_{10} - L_{90})2}{60} \qquad (5)$$

where L_{10}, L_{50}, and L_{90} =Sound level is equal to or exceeded for 10%, 50% and 90%, respectively of the time.

III. RESULTS AND DISCUSSION

3.1. Background Noise Levels

The background noise levels of the eight units of the study area(A10 - Air Processing Unit, A20 - Thermal Reforming Unit, A30 - Catalyst Processing Unit, A40 - Intermediate Product Unit, A50 - Product Forming Unit, A60 - Product Stabilization Unit, A70 - Steam Generation Unit and A80 - Product Storage Unit) are presented in Figure 1. The noise level in the entire plant area exceeded the action level of 85 dBA. Noise levels of Units A20, A50, A30 and A40 exceeded the OSHA occupational exposure limit of 90dBA thereby increasing the potential for noise induced hearing loss among workers in these locations. Generally, this result revealed high background noise levels within the plant area, with Unit A20 accounting for the highest noise level of 102 dBA, while Units A10 and A80 have the least noise level of 86 dBA.

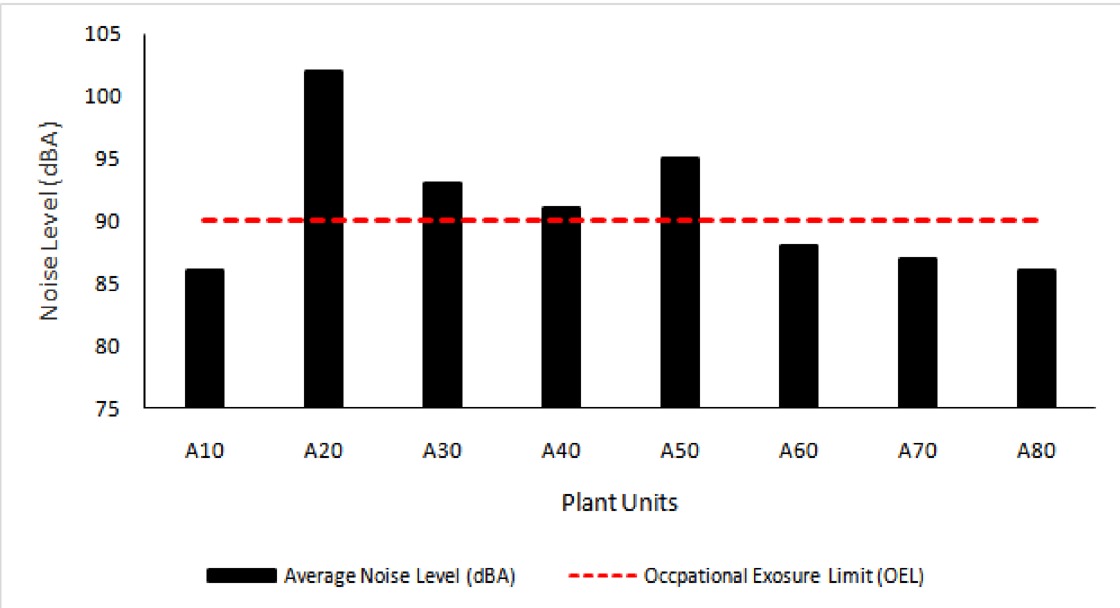

Figure 1: Background noise levels of units within plant area

3.2. Personnel Noise Levels

Personnel noise levels obtained from noise dosimetry measurement are presented in Figures 2, 3 and 4. The Time Weighted Average (TWA) of

19personnel out of 50 monitored exceeded the action level of 85 dBA. Figure 4 shows a moderate relationship between TWA and Dose. Generally, the results reveal a high potential for overexposure to noise among the workforce. Also, the results showed that most of the 19 personnel were Maintenance Technicians who spend more time working in high noise areas within the plant. This accounted for the high dose received by these personnel.

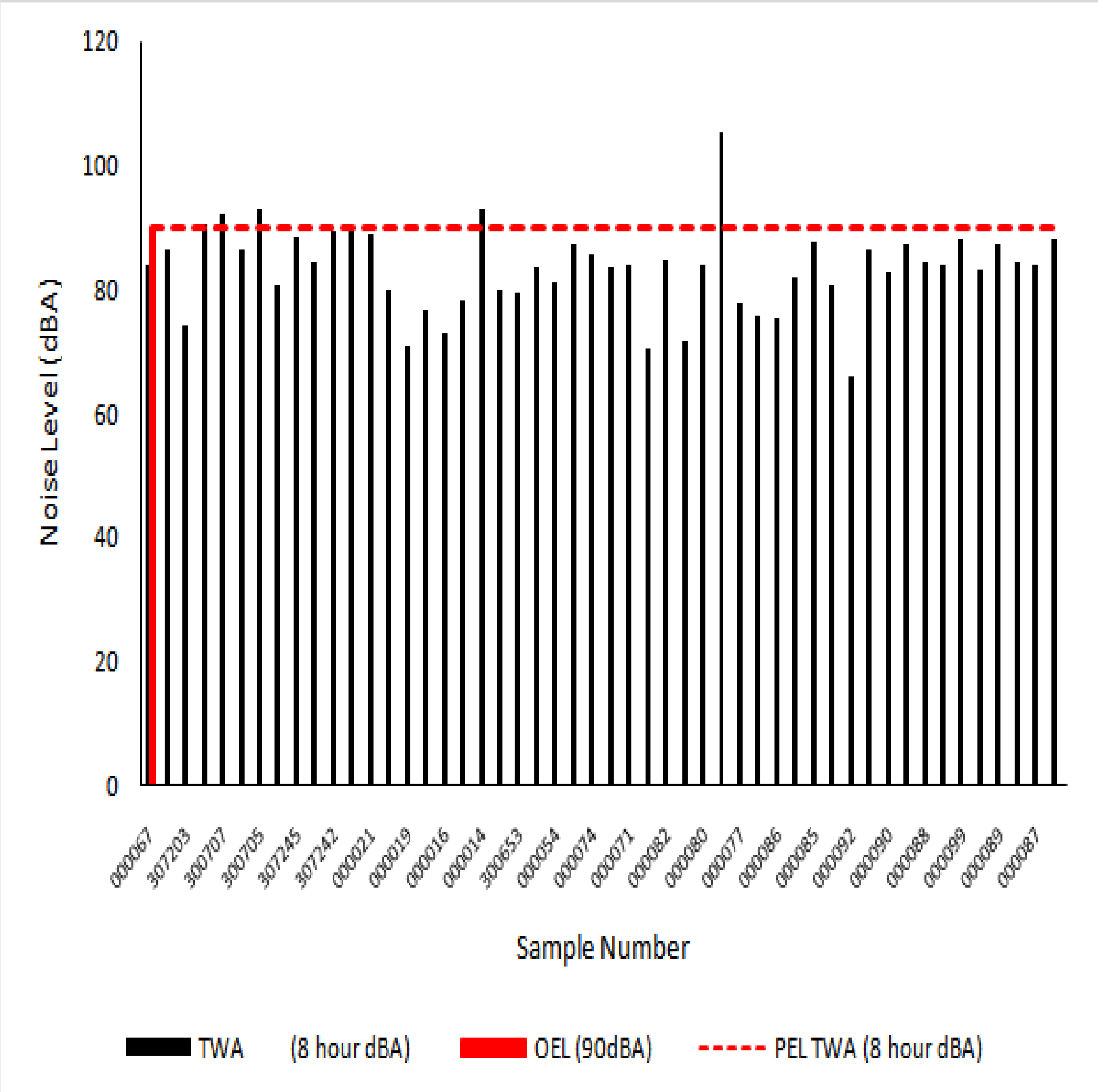

Figure 2: Relationship between time weighted average and permissible exposure limit

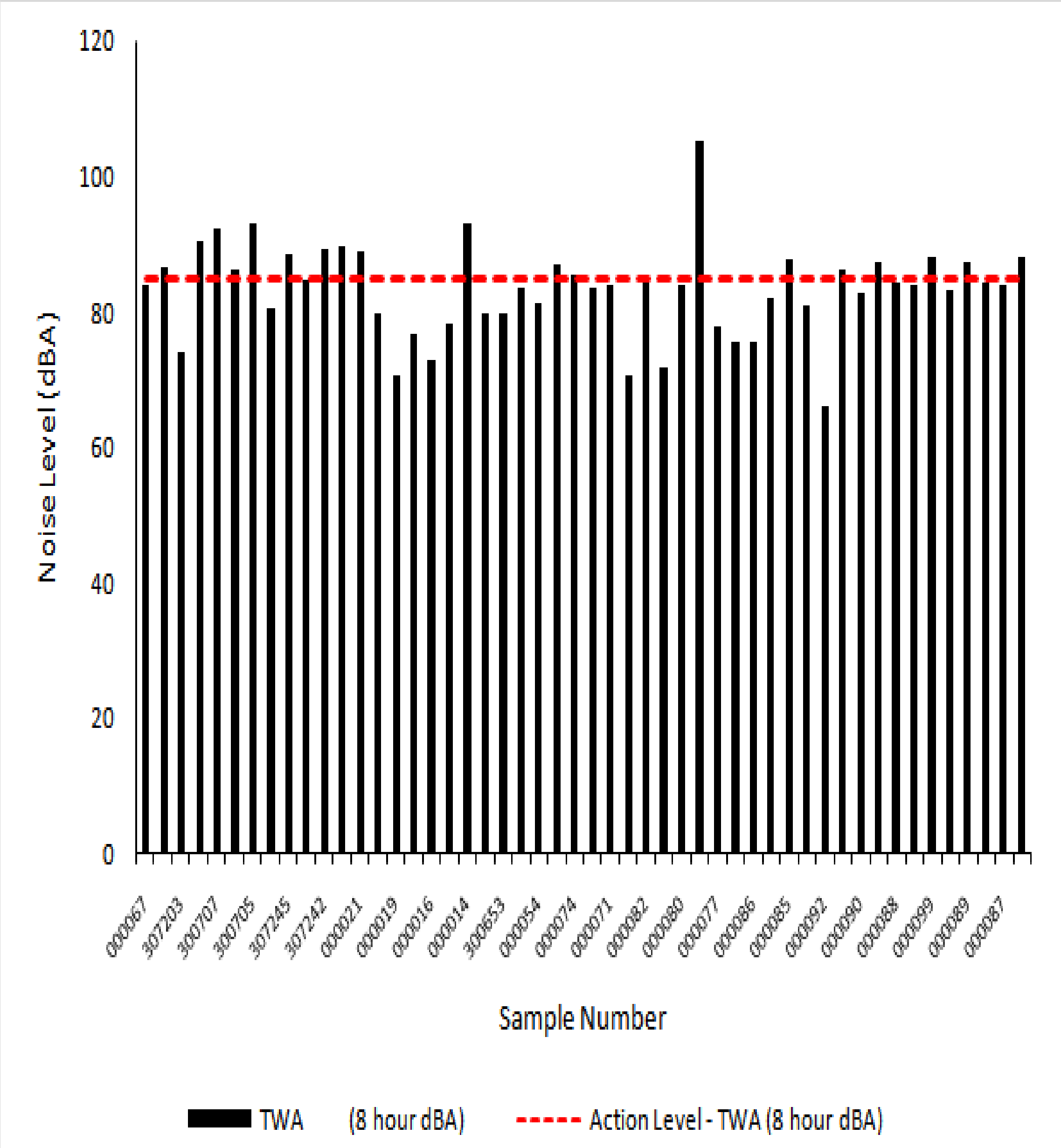

Figure 3: Relationship between time weighted average and action level

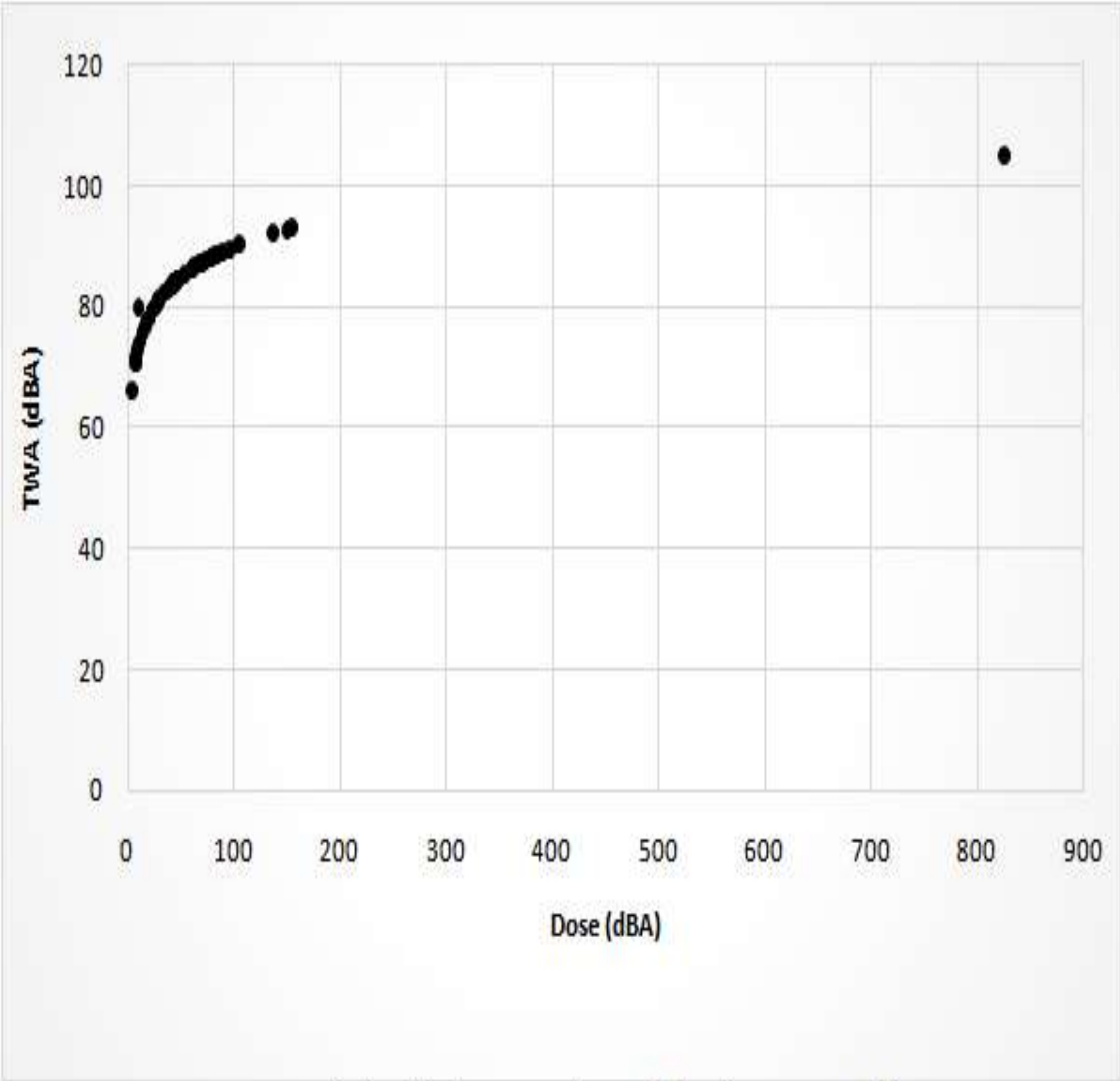

Figure 4: Relationship between time weighted average and dose

3.3. Audiometric Evaluation

The results of audiometric evaluation conducted for 19 of 50 monitored personnel who exceeded 85 dBA TWA action level are presented in Figure 5. The 19 personnel were enrolled in Hearing Conservation Program (HCP). The result obtained indicated that 4 (EG12, EG15, EG18 and EG20) out of the 19 personnel were 'Temporarily Unfit' which was an indication of a temporary loss of hearing. No case of permanent threshold shift was observed. The temporary threshold shift could be caused by many factors such as overexposure to noise due to poor engineering controls, incorrect use of hearing protection devices (HPD), use of HPD with poor attenuation rating, physiological fault in the ear canal of affected personnel. Further evaluation may be required to identify the exact cause(s).

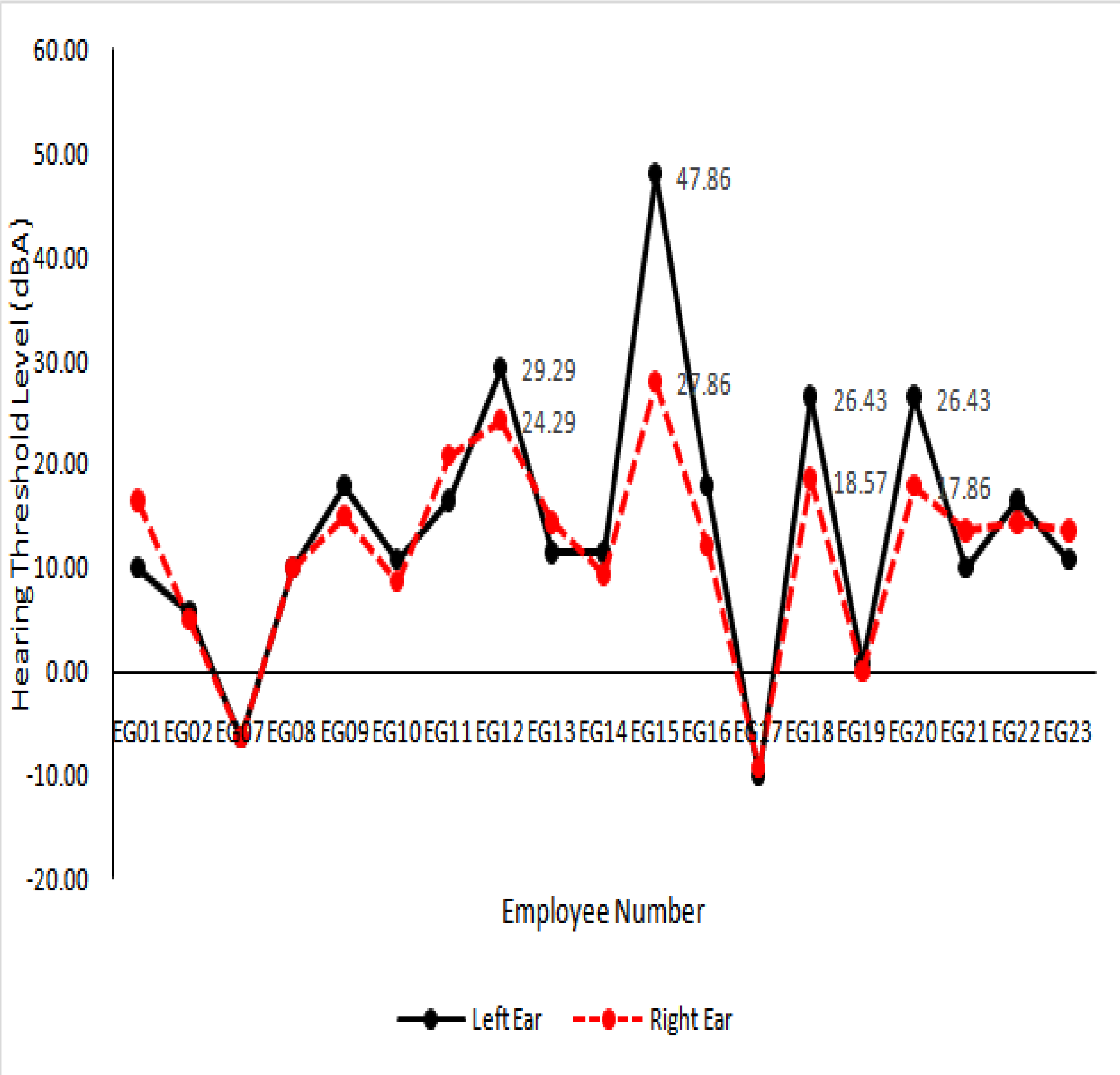

Figure 5: Left ear versus right ear hearing threshold

3.4. Hearing Fit Test

Results of Hearing Fit Test conducted for 19 personnel whose noise level exceeded action level of 85 dBA and were enrolled into the HCPare presented in Figure 6. Results showed that 4 of 19 personnel tested failed the Hearing Fit Test.The 4 personnel who failed the hearing fit test were the same personnel who were confirmed 'Temporary Unfit' in the audiometric evaluation (EG12, EG15, EG18 and EG20).

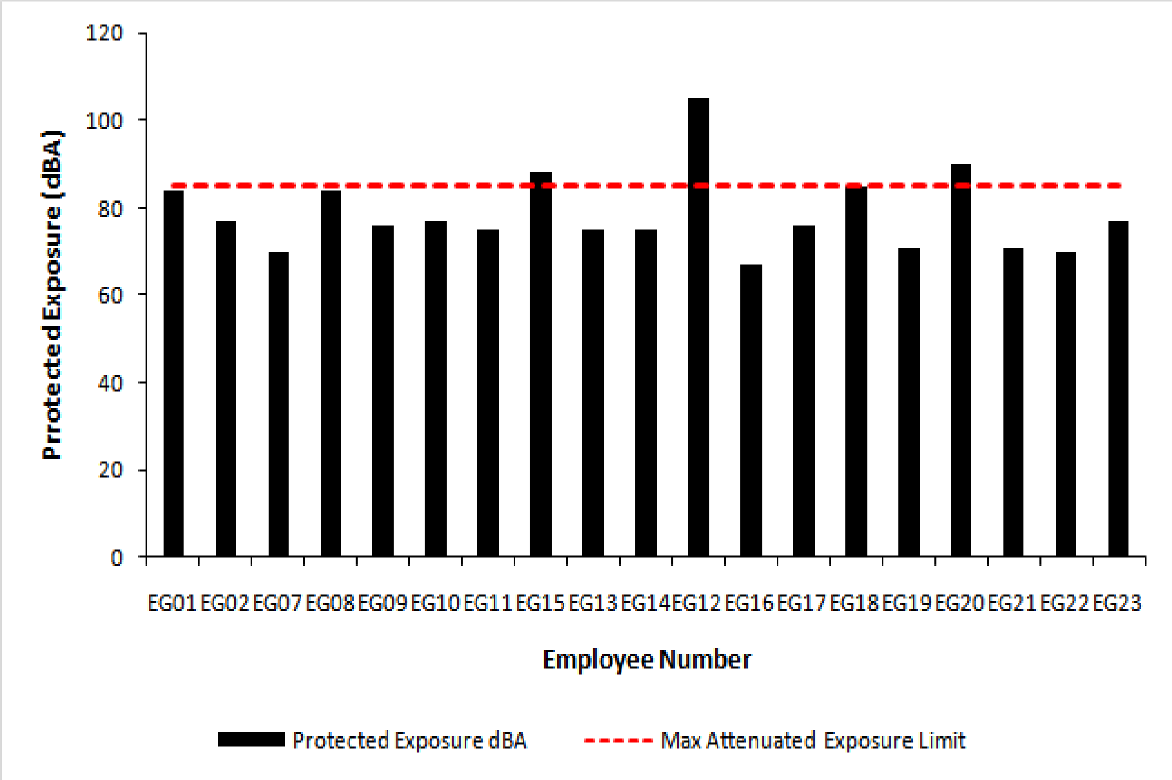

Figure 6: Hearing fit test

IV. CONCLUSION

A study of occupational impact of oil facilities noise on workers in an oil and gas facilitywas carried out. Results obtained from field measurements showed that continuous background noise levels within the entire plant area were above the 85dBA National Environmental Standards and Regulations Enforcement Agency (NESREA) permissible exposure limit andaction level for Occupational Safety and Health Administration (OSHA) 8hour permissible exposure limits for factory/industrial environments.The main finding of this research is that noise is a significant risk factor in oil and gas operations and that damage to and loss of workers' hearing is a serious possibility for those who are not wearing, or not correctly wearing, hearing protection. It has been shown that workers in A20 (Thermal Reforming Unit) experienced the highest exposure due to the presence of three gas turbine generators and other complex operations which accounted for the high background noise levels. The study revealed incidences of hearing loss (temporary threshold shift) among workers. This was corroborated by results of the hearing fit test which further confirmed that personnel with temporary threshold shift failed the hearing fit test. The most vulnerable similar exposure group (SEG) to noise were the Maintenance Technicians that were made to spend longer working time within different areas in the plant and because of additional noise generated by the tools regularly used for maintenance repairs within those high noise areas. Therefore, it is recommended that regular monitoring of workers exposure to noise should be carried out especially when there is a change in facility design or increase in the background noise levels.

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