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Noise Exposure and Its Auditory Effect on Industrial Workers

Ifeoluwa Victor Owolawi

Clinical Audiology and Hearing Therapy, School of Advanced Education, Research and Accreditation (SAERA), Valencia, Spain
Email: owolawivictor@hotmail.com

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Abstract

This paper analyzes the effect of exposure to noise among industrial workers in Nigeria to discover the level of exposure to noise that causes auditory defects or noise-induced hearing loss (NIHL), this paper primarily covers the evaluation of hearing impairment and its severity on exposure to loud sounds (acoustic trauma) and the role of hearing protective devices for industrial workers for prevention of Noise Induced Hearing Loss (NIHL). The paper also discusses the findings and guides as preventive methods for such industries. A total sample of seventy (70) workers were selected from three (3) manufacturing industries for this study. This study revealed a statistically significant difference in the hearing threshold within the selected industries over the selected period of time relating to the theory of excessive noise present in a given environment tends to affect people or in this case study employees hearing if proper hearing protection isn't used for prolonged hours or time, the study also surveys the various effect of noise on human health including various steps of noise control in such settings.

Keywords

Noise, Noise Induced Hearing Loss, NRR, Auditory System, Hearing, Hearing Protective Devices, Acoustic Trauma

1. Introduction

It has been established that noise could lead to increased accident and loss of productivity in industries but, what is considered noise? Noise as an unwanted sound is considered unpleasant, loud or disruptive to hearing. Noise can be viewed in terms of intensity or amplitude and frequency [1]. Sound/noise levels are measured in units as decibels (dB). To determine the sound pressure level (SPL) in the atmosphere or a given space sound meters are used. A scale of rea-

soning has been set in place to make the public aware of the dangers of noise at different sound pressure levels and duration. At 20 - 50 dB we find sounds like whispers and a quiet home, at 50 - 70 dB we find normal conversations and average office, at 70 - 80 dB we find traffic sounds and a noisy office, at 80 - 90 dB we find lawnmower sounds and loud radio, at 90 to 100 dB we find power tools sounds and noisy factory at 100 - 120 dB we find sound like disco clubs and loud rock concerts, at 120 - 140 dB we find sounds like gunshot and jet takeoffs [2] [3]. What are hearing protective devices? A hearing protective device is an ear protection device worn in or over the ears while exposed to hazardous noise to help prevent noise-induced hearing loss. Hearing protective devices reduce (not eliminate) the level of noise entering the ear. These devices are very important, as they decrease the risk of excessive noise exposure and subsequent hearing loss when worn properly. They come in different forms like ear muffs, ear plugs, electronic hearing protection device, semi insert device canal cap, etc. [4].

The National Institute for Occupational Safety and Health [5] provides recommendation on noise exposure in the workplace as the recommended exposure limit (REL) of noise in an occupation setting to 85 dBA for 8 hours using a 3 dB exchange rate (every 3 dB increase in level, the duration of exposure should be cut in half, *i.e.*, 88 dBA for 4 hours, 91 dBA for 2 hours, 94 dBA for 1 hour). According to NIOSH, excessive noise is essentially a form of energy having a sound pressure level of 85dB or higher. This energy is transmitted through the air as pressure waves and the use of specialist equipment is required when calculating average noise level exposures, e.g., sound meters.

Excessive noise can cause a temporary threshold shift from short-term exposure to high noise levels, with normal hearing returning after a period of rest or a permanent threshold shift after prolonged exposure to high noise levels, which can cause physiological fatigue, tinnitus, a ringing or buzzing in the ears or head, increased blood pressure and stress, inability to sleep, fatigue and other sleep problems, a sense of isolation and interference with general workplace communications, and inability to hear warnings of imminent safety hazards due to excessive noise.

Noise induced hearing loss can either be acute or chronic. The acute type can be caused by "acoustic shocks" from things like fireworks or small gun fire, while the chronic type follows a prolonged exposure to high intensity level of noise usually found in manufacturing industries or aircraft stations. Four phases can be distinguished in the chronic form of noise-induced hearing loss, the first phase being ringing in the ears and a sensation of fullness of the ears in approximately the first 20 days of exposure, sometimes accompanied by slight headache and dizziness. The second phase occurs after a few months, where the person experiences intermittent ringing in the ears. The third phase starts when the person notices hard of hearing difficulty in hearing the ticking of the clock, difficulty in understanding components of conversation and increasing the volume of television to understand what is being said. The fourth phase starts when the feeling of hearing insufficiency is manifest, this is when any type of communication us-

ing acoustic signals is impossible or very difficult to understand.

The World Health Organization [6] defines hearing loss as the inability to hear as well as someone with normal hearing (<25 dB), while "hard of hearing" refers to people with hearing loss ranging from mild to severe (26 - 90 dB) and "deaf" to people who mostly have profound hearing loss (>90 bB), which implies very little or no hearing. Noise-induced hearing loss is sensory deafness caused by long-term exposure of the auditory system to a noisy environment auditory fatigue is an early sign of noise-induced hearing loss and can gradually recover from after an exit from the noisy area. However, if noise is too prolonged in time, hearing will become permanently impaired. The symptoms of noise-induced hearing loss include difficulty in hearing voices at high frequencies difficultly in understanding speech, social isolation from co-workers, family and friends. Occupational noise-induced hearing loss is hearing loss that develops slowly over a long period of time (several years) as the result of exposure to excessive noise at work.

2. Objectives

The primary objective of this study is to indicate that exposure to noise above 85 dBA for extended period can cause NIHL or a form of auditory related issues, as stated in the Walsh-Healey act [7]. When a person without any form of hearing protection is immersed in a noisy environment of sound level over 85 dBA for over 4 hours, the person will experience a form of noise-induced hearing loss either a temporary threshold shift or a permanent threshold shift because of the exposure to such level of noise. Secondly, it is commonly believed that any form of hearing protection device alone will be sufficient in reducing the noise exposure to the user which brings us to the secondary objective of this study. This objective states that adequate hearing protection reduces exposure to noise, which leads to permanent auditory disabilities, while adequate is the keyword of this objective, because hearing protective devices reduce the level of noise entering the ears but does not cancel the noise from the environment. NRR is an abbreviation for Noise Reduction Rating, every ear protective device has an average level of hearing protection (noise) it cuts out for the user if used properly [8]. The NRR is a number measured in decibels. It is intended to help the user compare the amount of noise being reduced by the hearing protection device(s). The higher the NRR, the more noise is being prevented from entering the ear. A device with an NRR of 30 will provide more protection against damaging noise than a device with an NRR of 25.

3. Methods

3.1. Participants

A total of seventy (70) workers were selected from three (3) industries (industry A, industry B, industry C). Workers were selected from two departments (power plant and administration). The power plant workers work on two shifts of 12

hours daily and the admin workers work 8 hours daily in all four industries, a total of fifty (50) power plant workers from each shift were selected to participate in this experiment and also twenty (20) administrative workers in total from the three (3) industries.

3.2. Design

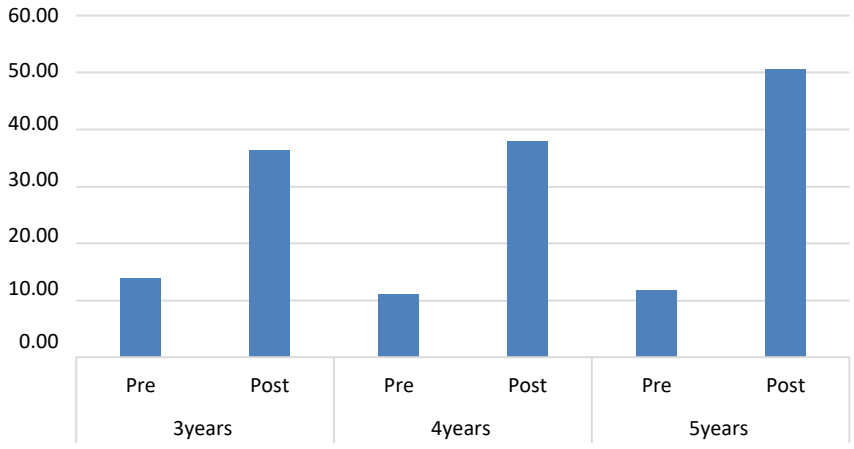
A comprehensive questionnaire was filled by each participant to determine their life style and eligibility (which suitable candidates were selected), after which a sound level was required for each working environment, followed by a comprehensive hearing evaluation taken by all participants. This will serve as our reference point or post-test measures. The power plant workers are the experimental group and the administrative workers will be the control group. The requirements to qualify for the experiment are:

- Having a clean bill of health.
- Not having a history of past chronic noise exposure prior to joining the industry
- Years of experience in industry (3 - 5 years).
- Under the age 45.
- Having done a pre-employment hearing evaluation in the industry.

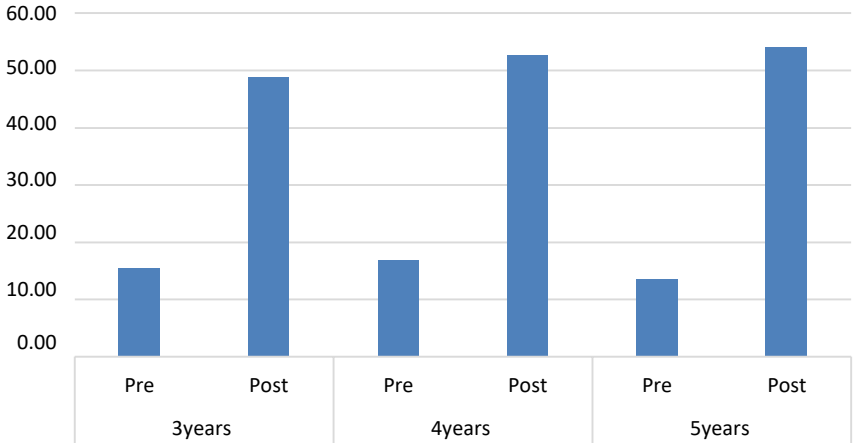
In industry A, the administrate complex is situated 2000 meters from the power plant and recorded a sound level of 50 dBA, while the power plant recorded a sound level of 110 dBA. In industry B, the administrate complex is situated 1800 meters from the power plant and recorded a sound level of 50 dBA, while the power plant recorded a sound level of 115 dBA. In the case of industry C, the administrate complex is situated 1500 meters from the power plant and recorded a sound level of 60 dBA, while the power plant recorded a sound level of 115 dBA. A hearing test was conducted for the 70 workers over a period of two days for each industry (this test will serve as our post-test measures). The test for the power plant workers was done ten hours after each shift to avoid temporary threshold shift (TTS), while the administrative workers had the test done before the beginning of the days' work. Hearing protection devices were put into consideration, two of the companies use mid-standard ear muffs only (electronic ear muffs), while the industry C uses a custom earplug (Hass industrial Noise Ban) together with ear muffs (electronic ear muffs), as hearing protection devices which ought to protect its employees from hearing loss. After the screening of all workers an evaluation of NIHL between all industries (**Graphs 1-3**) over 3, 4 and 5 years will be examined to draw a conclusion (**Graph 4**).

4. Results

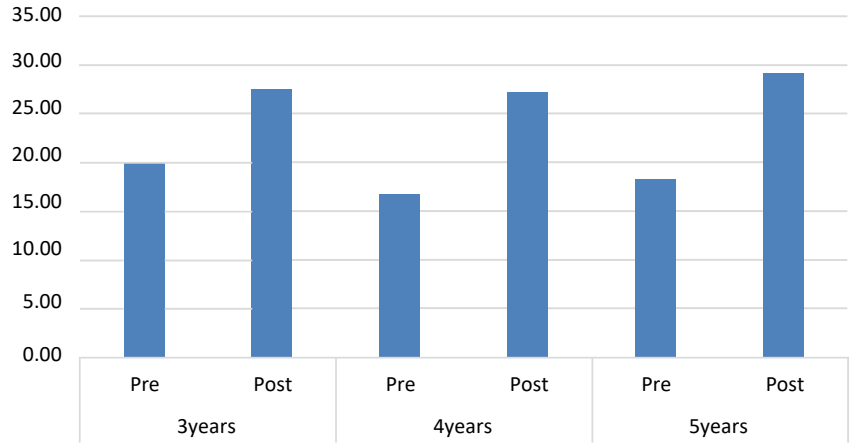
The pure tone average (PTA) is calculated by the thresholds of 0.5, 1.0, 2.0 and 4.0 kHz/4, while PTA value is the summation of left and right PTA divided by 2. The mean is calculated as the summation of PTA value divided by number of frequencies and Standard deviation (SD) is calculated using sqrt $((x\text{-mean})^2/n-1)$.



Graph 1. NIHL evaluation of power plant workers after 3, 4 and 5 years in industry A.

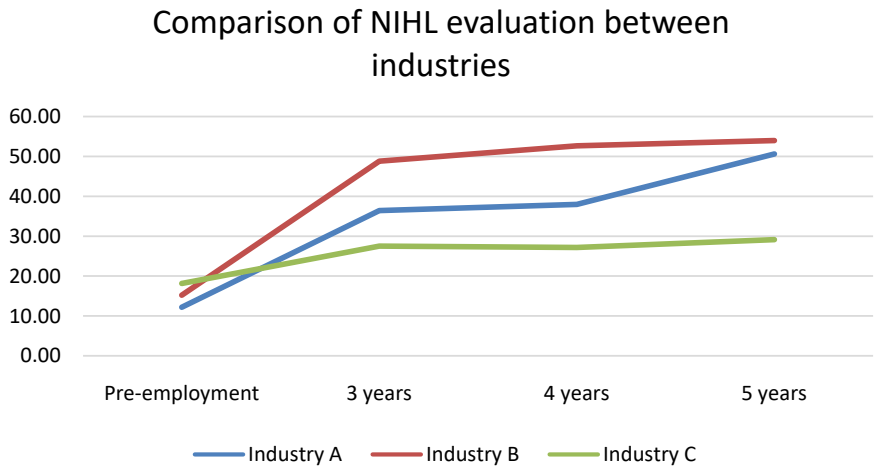


Graph 2. NIHL evaluation of power plant workers after 3, 4 and 5 years in industry B.



Graph 3. NIHL evaluation of power plant workers after 3, 4 and 5 years in industry C.

Findings from industry A (Graph 1) showed an increase in hearing loss over time in all power plant workers (*i.e.*, from employment to 5 years mean value = from 11.75 to 50.63), with most having a noise notch in their respective audiometric thresholds findings (Figure 1).



Graph 4. Evaluation of NIHL between industries over 3, 4 and 5 years.

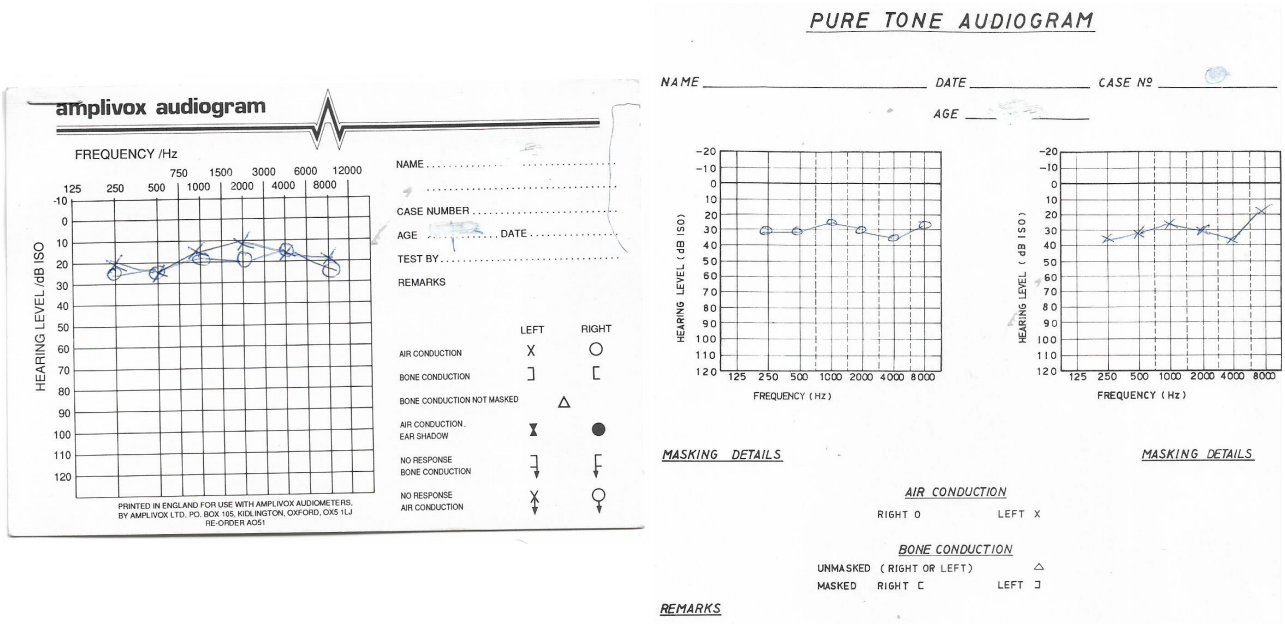


Figure 1. Pre and post pure tone audiogram of a worker from industry A.

Findings from industry B (Graph 2) showed more increase in hearing loss over time in all power plant workers compared to industry A, also having a noise notch (Figure 2) (*i.e.*, from employment to 5 years mean value = from 13.40 to 54.00).

Findings from industry C (Graph 3) however showed a very slight increase in hearing loss over time in all power plant workers but drastically reduced compared to results from industry A and B with no noise notch present (*i.e.*, from employment to 5 years mean value = from 18.25 to 29.13).

Note: in Figures 1-4 the pre-test audiogram is on the left and post-test (5 years) audiogram is on the right.

Mean values of employees from industry A before employment is 12.19, while from industry B is 15.22 and for industry C is 18.17 (Graphs 1-3).

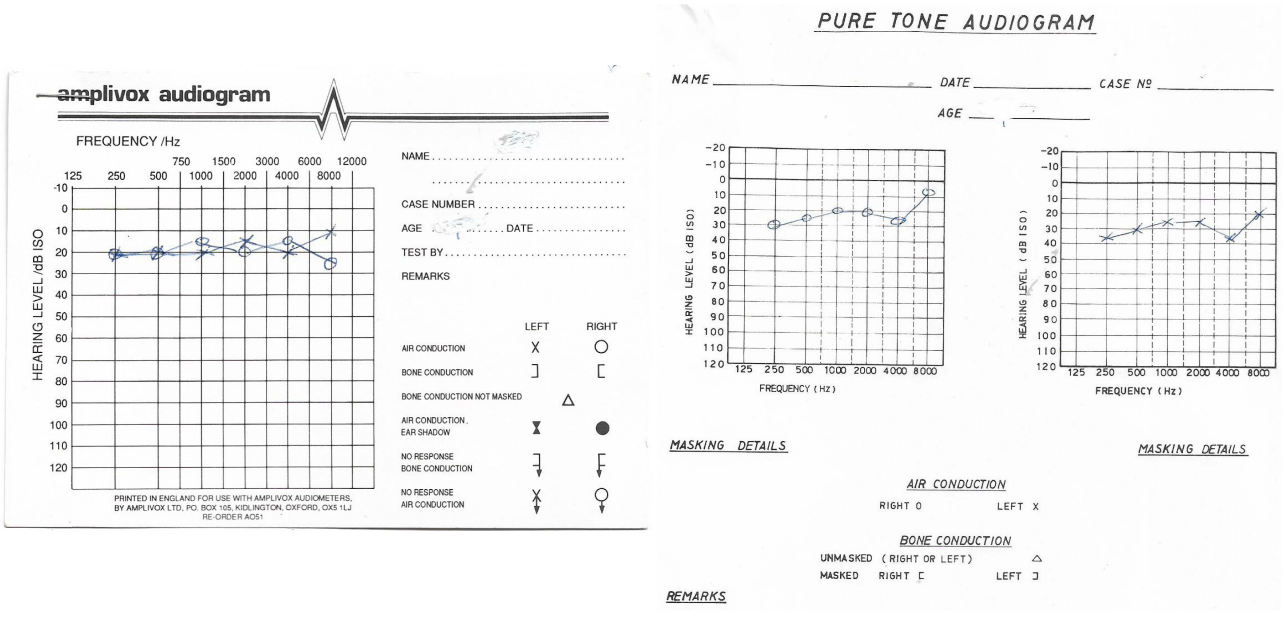


Figure 2. Pre and post pure tone audiogram of a worker from industry B.

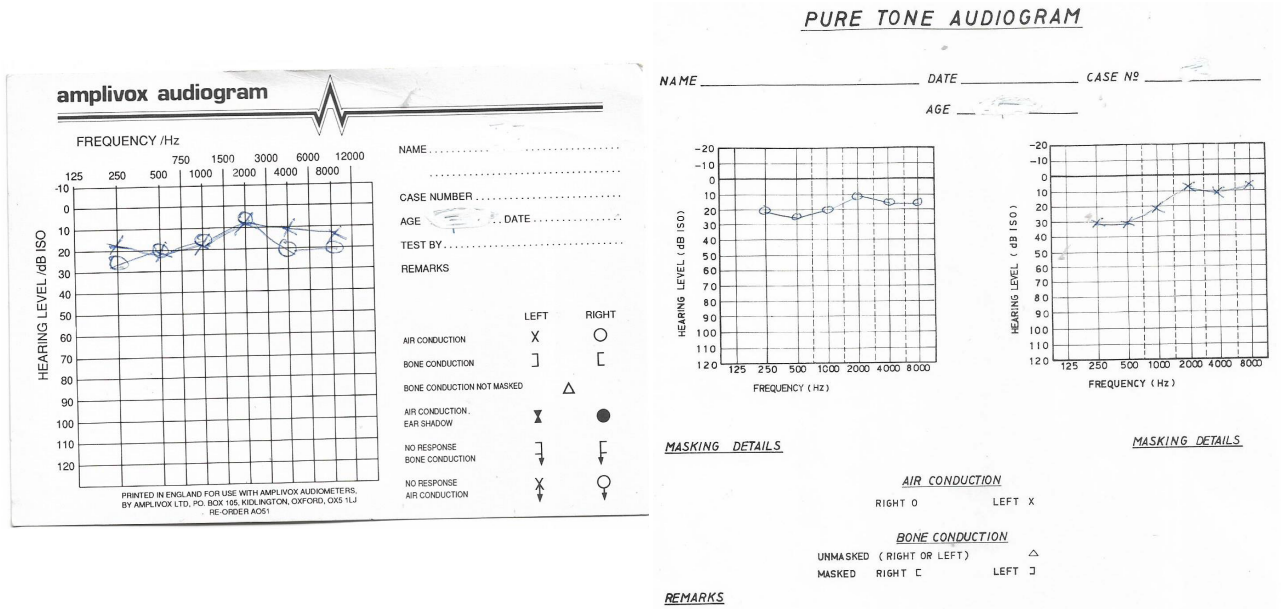


Figure 3. Pre and post pure tone audiogram of a worker from industry C.

The mean and standard deviation of PTA values for three years of employment of all three industries are (Mean = 37.58, SD = 10.71).

The mean and standard deviation of PTA values for four years of employment of all three industries are (Mean = 39.28, SD = 12.79).

The mean and standard deviation of PTA values for five years of employment of all three industries are (Mean = 44.59, SD = 13.49).

From the above data (**Graph 4**) we can see what happens to the employees hearing if proper hearing protection isn't used against noise for prolonged hours or time. As time passes the level of noise induced hearing loss (NIHL) or auditory

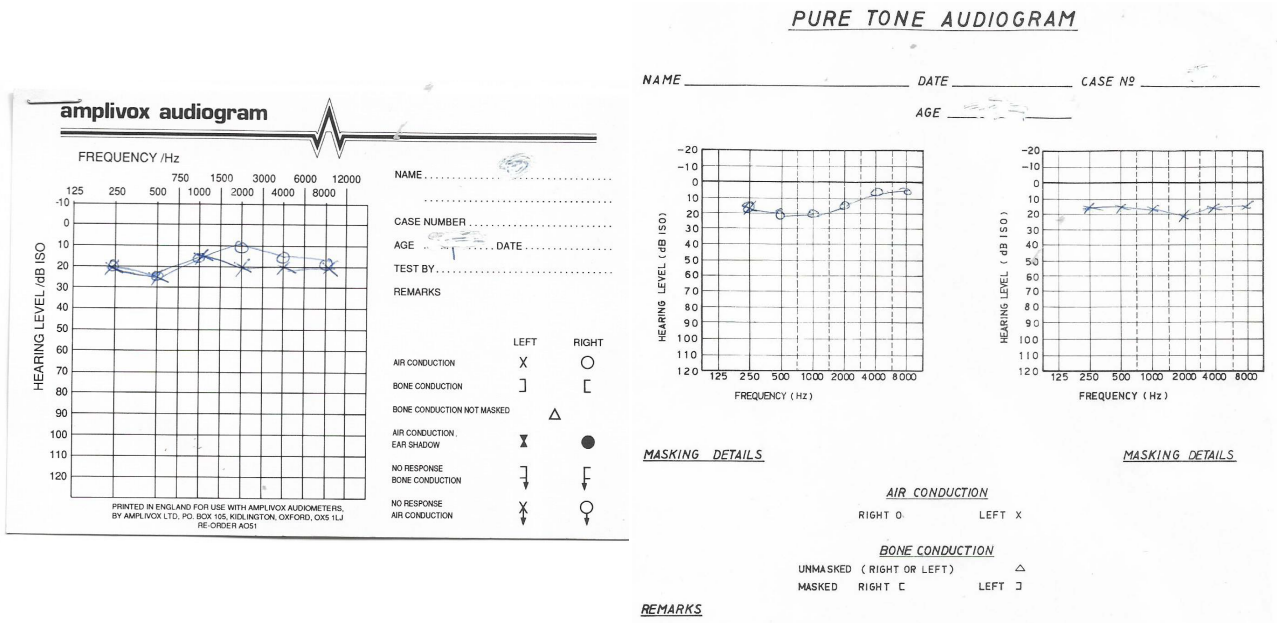


Figure 4. Pre and post pure tone audiogram of a worker from the control group.

related issues increases. For an industry like industry C which makes use of two hearing protective devices (ear muffs and Ear plugs) we see that the mean values increased slightly between the 3rd year to 5th year with no noise notch present, compared to industry A where the value almost doubled over a two-year period, this can be attributed to inadequate hearing protection used in industry A and also industry B.

5. Discussion

According to the findings made from the three industries, it is clearly seen that the most affected set of power plant workers are the workers from industry B. This is solely based on the present noise level in the industry and the degree of hearing protection provided being used is not sufficient proper attenuation and protection of its power plant workers. Industry B recorded a sound level of 115 dBA in the power plant, the hearing protection utilized is an ear muff which according to the NRR rating will be able to cut out about 25 dB making the workers to perceive a noise level of 90 dB for up to 12 hours daily, which places the workers in an environment where they are exposed to excessive noise exposure for a prolonged time, which is dangerous for the auditory system.

Industry C also recorded a noise level of 115 dbBA but makes use of a combined ear muff and ear plug, the ear muff attenuation level has a NRR rating of 25 dB and the ear plug has a NRR rating of 30 dB, leaving the powerplant workers auditory system exposed to 60 dB of noise if the protective devices are used properly and adequately. The findings from industry C showed a little bit of hearing loss over time, this can be attributed to age associated hearing loss (AAHL) or workers negligence to safety.

In industry A, a sound level of 110 dBA was recorded. The industry uses an

ear muff of noise attenuation level of 25 dB. From the NRR rating, leaving the workers in a working environment of 85 dB, findings from industry A showed a slow but rising level of hearing loss over time in the workers. This is due to the extended time level of sound pressure the power plant workers are subjected to daily.

We can see that from the third year, some level of loss of hearing are already present in industry A and industry B. This suggests that before three years of noise exposure, if no proper or adequate hearing protection is used a hearing loss is bound to occur in such environment. The increase in PTA values over time (years) shows or correlates with all other theories that duration of time or exposure to excessive noise affects the auditory system. As seen in the results section, the greater the hearing protection used or the higher the NRR rating the hearing protection device used, the lower the NIHL progression in the employees over time, Industry B and Industry C both have the same noise level but the employees in Industry C seem to be less affected by the noise compared to the workers in Industry C, this phenomenon can be linked to the use or lack of use of adequate hearing protective devices.

Most of the affected workers showed physiological reaction to noise in form of pupillary dilation, which is linked to sound intensity than initial effects of fear or pain. Other complains were of irritability, nausea, tension, fatigue insomnia, sore throat from over shouting in the noise, blood pressure changes, induced tinnitus and a sensation of fullness in the ears irrespective of industry Most industrial workers are aware of the uses and benefits of hearing protection device as it is a helpful tool to avoid the harmful effect of noise to the auditory system, only few make proper use of it. In a study in South Africa, gold miners were found not making use of hearing protective devices as a show of bravery [9]. Also, in South Africa in a case where platinum miners were exposed to noise level of 91 - 105 dBA without adequate hearing protective equipment, where occupational noise induced hearing loss was found in most of the employees, though most have been working there for over ten years [10]. A case also emerged in Zimbabwe in a mine where workers were exposed to noise of up to 103 dBA, while the workers claimed that no hearing conservation program has ever been conducted at the mine [11].

Another factor which is often over looked is the aspect of excessive noise affecting the vestibular system, in the city of Jordan a noise exposure study was made to discover the effect of noise on the vestibular systems of dental technicians who have been working in the laboratories for years been exposed to noise levels of 85 dB or greater, where some of the participants experienced some form of vestibular impairment, including benign paroxysmal positional vertigo (BPPV), endolymphatic hydrops (Meniere disease), or a combination of both, the study drew the conclusion that exposure to loud/excessive noise in dental laboratories severely impacts the functioning of the vestibular system of the inner ear more than the cochlea [12].

6. Conclusion

In conclusion, the present study has revealed that the constant exposure to noise (occupational) causes a reduced hearing perception as showed by the increasing hearing threshold of the study participants. Therefore, there is a need for both individuals and government appointed bodies to try to curb or put together a means of reducing the risk associated with noise, especially at workplaces, because as shown in this study and others, it harms the employees and reduced productivity of the workers which in turn will reduce industrial productivity. The very first step will be to educate the workers/employees on the dangers and drawbacks of excessive noise on the auditory and related systems, while individuals should either reduce their daily exposure to noise or to excessive sound, meanwhile adequate hearing protective devices should be used properly in places with a high or extreme noise levels, manufacturing industries should inculcate hearing monitoring and hearing conservation programs at regular intervals (pre-employment, annually and at exit) this is quite important to avoid medico-legal cases on claims of work-related disabilities due to exposure to excessive noise without adequate measures in place for its workers. While the government can help by enforcing laws to regulate the environmental noise levels in the industries and to take up the task of informing the public on the dangers of excessive noise on the auditory system or related systems, they can also embark on tasks such as constant monitoring of mega cities and regular noise level checks/verification, as well as conduct regular hearing assessments or hearing screening for those who work or reside close to noisy environments.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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