Fall 2021

Effects of Ototoxic Chemicals and Occupational Exposure to Humans

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19 November 2021

Abstract

The primary aim of this capstone paper was to review and examine previous works of literature on the effects of ototoxic organic solvents and various heavy metals on the auditory structure due to occupational exposure. Additionally, the research also focused on identifying work environments, which are characterized by such ototoxic toxins. The method for picking organic solvents and heavy metals encompassed the existing data that signified that such chemical substances could induce auditory challenges among workers in divergent work settings. Furthermore, the ambiguities of the publications were also extensively considered before they could be incorporated in this research. References to occupational ototoxicity were celebrated for organic solvents like styrene, toluene, carbon disulfide, trichloroethylene, and arsenic compounds. The references for heavy metals such as mercury and lead were also noted.

Consequently, the publications were able to show that these substances induce extensive damage to the auditory system, especially for those who experience prolonged occupational exposure. It was also noticed that occupational exposure to hazardous noise plays a critical role in work-related hearing loss, especially when combined with these substances. The gad in literature was also identified since it is challenging to examine the ototoxic effects of individual chemicals since work environments are characterized by numerous substances that contribute significantly to auditory challenges like deafness and tinnitus.

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1.0 Introduction

The hearing loss reflects the effects of ototoxic occupational chemical exposure to humans. However, certain chemicals have mild to severe loss of hearing, deafness, or tinnitus. Addressing risk factors of ototoxic occupation chemical exposure, occupational ototoxic chemicals, effects on the ear, preventive and corrective measures can significantly scale down risks of workplace exposure to ototoxic chemicals. Therefore, gaining a comprehensive understanding of the accuses of hearing loss among employees in various industries is vital in developing robust remedial measures that can help mitigate their deteriorating health conditions associated with such complications. In developed nations such as the U.S., hearing loss is one of the leading chronic physical ailments in the adult population. According to various studies, over 2 per cent of the working adults in the U.S. are dealing with hearing complications (NIOSH, 2019). Among this group of people, occupational exposure to ototoxic substances and loud noises in the working environment are the primary causes of their auditory health challenges. Furthermore, issues like tinnitus, which is constant ringing of the ear and various forms of hearing complications, are highly prevalent among these populations.

The major causes of hearing challenges among workers are exposed to extreme noise and ototoxic chemicals or substances. Noise becomes hazardous to humans when it is beyond 80 decibels or if individuals are compelled to speak loudly to someone who is approximately 3 feet far. According to the National Institute of Deafness and Other Communicable Disorders, noise-induced hearing loss can stem from on-time exposure to extreme noise or persistent exposure to high impulse noise over a long period like loud noise in various workplaces or factories (National Institute of Deafness and Other Communication Disorders, 2019). Another primary cause of hearing loss in the workplace is exposed to multiple types of ototoxic chemicals. Such substances usually make the auditory system more vulnerable to the destructive consequences of hazardous noise. For instance, persons under certain ototoxic drugs might lose their hearing abilities become highly exposed to perilous noise or both. Examples of ototoxic substances include solvents (toluene, styrene, and trichloroethylene), pharmaceuticals such as various forms of antineoplastic agents, metal substances like mercury, organic compounds, and lead, and asphyxiates, which entail hydrogen cyanide and carbon monoxide. When individuals are constantly exposed to one or more of these chemicals, they gradually develop hearing complications, which sometimes lead to total deafness. Currently, most global populations are exposed to either loud noise, ototoxic chemicals, or both in their work environments. Thus, indicating that many people are coping with either milled or severe auditory conditions. Therefore, it is a matter of intervention that industries are encouraged to adopt robust employees' healthcare policies that advocate for healthy work environments.

Therefore, this project will isolate certain risk factors and chemicals associated with ototoxic occupational chemical exposure to address these challenges. Moreover, it will discuss existing occupational safety policies, measures to prevent workers' exposure to chemicals, conduct surveys, and program evaluations. Advocate for occupational safety guidelines awareness and corrective actions for already affected workers, highlight challenges and opportunities for occupation safety, and recommend organizational practices to guarantee occupational safety.

1.1 Objectives of the Project

The primary objective is to offer guidance to employees and employers on ways to avoid ototoxic chemical occupational exposure, provide basic guidelines to prevent chemical exposure, and provide opportunities for improved occupational safety. Moreover, the rise of ototoxic in the workspace reflects the mystery of hearing loss among workers. Numerous studies have extensively investigated the underlying causes, challenges, effects, impact, and preventive measures of ototoxic. The ultimate goal is to develop quality and quantity information to be used by doctors and administrations to minimize the number of workers suffering permanent hearing loss. Therefore, the author of this senior project hopes to identify chemicals and factors that cause ear impairment, especially in the workplace. According to Mayo Clinic (2021), risk factors include industrial chemicals, occupational noise, and exposure to firearms or explosives noise in occupational settings. The project will deliberate on how each element causes auditory system impairment to identify how the human body absorbs toxins. The project identifies challenges that make it hard to treat and diagnose ototoxic to enable medical personnel to find solutions for the challenges. Additionally, the author has included ototoxic effects to fill up the information gap about ototoxic.

The effects stated are intended to help health professionals to develop ways of detecting ototoxic in its early stage. Therefore, this project is done hoping that the information obtained on effects, challenges, and how the body absorbs the ototoxic toxins can provide an effective remedial procedure capable of scaling down the number of workers who suffer permanent hearing impairment due to exposure. According to Ganesan et al. (2018), a timely diagnosis of ototoxicity is a significant way of addressing auditory complications and preventing permanent hearing loss. Moreover, the project will highlight various ototoxic occupational exposure measures to help managers and business owners identify multiple ways to protect employees against ototoxic substances. Through this project, the author hopes to inspire various administrative departments to assess their workers' environment to determine whether such factors can negatively affect their employees' health and take necessary preventive measures to protect their workers.

1.2 Problem Statement

Over the years, there has been a significant rise in the number of people coping with auditory complications due to exposure to either hazardous noise or chemical substances in their work environments. For instance, Estill et al. (2017) state that over 5,000 people experience occupational-related injuries, and about 22 million others are exposed to unbearable noise conditions in their workplaces. Additionally, divergent types of solvents characterize numerous industrial processes such as painting, textile production, agricultural activities, aviation, and the use of adhesives; this suggests that many workers around the globe are exposed to one or more of these solvents substances in their work situations. For example, numerous studies have indicated that many American workers have been exposed to such dangerous solvents; thus, a good percentage of these people are dealing with auditory issues like tinnitus, partial deafness, or permanent deafness (Estill et al., 2017). The primary type of these solvent chemicals that have plagued many workers in different occupations is the organic solvents; this is because organic solvents have extensive applications in numerous industries around the globe (Loukzadeh et al., 2014). According to various studies, over nine million employees work in environments characterized by organic solvents. These solvents include cyclic hydrocarbons, alcohols, esters, aldehydes, aliphatic hydrocarbons, and halogenated hydrocarbons. These chemicals are undoubtedly damaging to the human body, especially the auditory canals. In 2014, Loukzadeh et al. indicated the ototoxicity of organic solvents in their studies involving rat models.

Moreover, it was also noticed that the combination of both hazardous noise and organic solvents significantly increases the rate of hearing loss compared to hazardous noise alone. Thus, suggesting that exposure to such organic compounds is associated with relatively high chances of noise-induced auditory issues because organic solvents expose the ear's outer hair cells to become highly vulnerable to noise (Loukzadeh et al., 2014). As a result, the protective capacity of the middle ear is significantly scaled-down since the protective reflexes such as acoustic reflexes are severely suppressed. Consequently, there is a high level of noise penetration into the inner ear, leading to extensive auditory damage (Loukzadeh et al., 2014).

Even though there are numerous pieces of literature on the ototoxicity and occupational exposure to organic solvents, audiologists have minimal awareness concerning organic solvent-induced hearing loss and other associated auditory complications stemming from other occupational exposures like hazardous noise; several factors fuel this situation. For instance, a good number of existing works of literature are focused on occupational health and not ototoxicity and occupational exposure to organic solvents that cause auditory challenges among workers in different industries (Loukzadeh et al., 2014). Clinically, the impacts of environmental solvents exposure might be associated with industrial noise levels thus; other potential factors that significantly contribute to ototoxicity are not considered. Therefore, this research is focused on reviewing previous works of literature performed on both humans and animals. The literature review will consider the auditory challenges induced by both hazardous noise and organic solvent exposure.

Consequently, the effects of organic solvent-hearing loss will be highlighted. Furthermore, potential diagnosis procedures examining the bioeffects of organic solvents and other factors contributing to hearing loss among workers will be scrutinized. Additionally, the possible rehabilitation requirements of individuals dealing with noise-induced hearing loss or organic solvent-induced hearing loss will be considered.

2.0 Literature Review

2.1 Ototoxicity and Occupational Exposure to Organic Solvents among Humans

Apart from hazardous noise, which is the primary source of auditory issues among workers in various industries, organic solvents are also a significant contributor to hearing issues experienced by such workers. Numerous organic solvents characterize many work environments. Some of these solvents include; Toluene, styrene, xylene, and ethylbenzene. These solvents cause extensive damage to the auditory structure, especially when individuals are exposed to extreme concentration levels. Therefore, they must be adequately examined to understand better, how it affects human beings' hearing systems.

2.1.1 Exposure to styrene

Styrene is an organic solvent extensively used in numerous industries, especially those handling synthetic fibres, glass, plastic, and resins. Therefore, innumerable employees working in these factories are in constant contact with styrene. Recent studies on various factories suggested that styrene concentrations range between 0.05 parts per million to 47 parts per million (Campo et al., 2013). Nonetheless, occupational exposures among humans are considerably high compared to averaged exposure levels to styrene in the work environment. For instance, some studies have indicated that exposure to styrene among workers range from zero to over 190 part per million, with an average mean of about 16.5 part per million (Campo et al., 2013). Even though styrene exposure has a significant potential of causing partial or permanent deafness, styrene-induced cochlea mutilation might not result in a complete loss of auditory abilities. Extensive studies on styrene ototoxicity in animals have shown that the chemicals that makeup styrene impair cochlea cells found in the middle ear leading to auditory damage in the mid-frequency location. This chemical focuses on the cochlea hair cells from the outer hair cells (OHCs) found in the third row and then proceeds to the second and first rows of the auditory system. Campo et al. (2013) suggest that Deiters cells of the ear are considerably susceptible to styrene exposure than the OHCs; this leads to styrene-induced cell damage, which occurs through a caspase-dependent apoptotic pathway. Various studies conducted on styrene ototoxicity on expectant women workers have indicated that exposure to styrene during pregnancy impacts infant weight and neurological activities of the brain; this shows that the occurrences of styrene in the body of an expectant woman can significantly influence the development of the auditory structures of the baby (Campo et al., 2013).

According to Muijser et al. (1988), a high rate of hearing complications among human beings is associated with exposure to high doses of styrene; this is because relatively high frequencies of auditory thresholds are noticeably elevated in individuals working in environments with high quantities of styrene (Loukzadeh et al., 2014). Nonetheless, the result of the research performed by Muijser and his associates concerning high-frequency hearing thresholds among employees exposed to styrene and those not exposed to styrene indicated that there was no significant variation. Other studies utilizing pure-tone audiometry failed to demonstrate any chronic styrene-induced impact on auditory acuity in occupationally exposed individuals. Estill et al. (2017) also give additional proof of the ototoxic consequences of styrene. According to Estill et al. (2017), the destructive chemical effect of styrene on the auditory system ranged from 2000 to 6000 Hz, while the odd ratio of auditory impairment stood at 2.44, which was relatively higher for each increment of 1mmol of mandelic acid. Mandelic acid is the biological marker of occupational exposure to styrene.

Furthermore, the study by Morata et al. (2017) also indicates that styrene can influence the mi-audiometric frequency of 2000 Hz. This finding is in line with the results of a previous study conducted by Sliwinska-Kowalska et al. (2001). According to the outcomes of these studies, even exposure to lower quantities of styrene can cause detrimental effects to the auditory structure.

2.1.2 Exposure to carbon disulfide

Carbon disulfide is another organic solvent that poses a significant threat to the auditory system, especially for those individuals working in environments containing high quantities of carbon disulfide elements. Additionally, it is a lipophilic organic solvent primarily used to manufacture viscose rayon and various agricultural activities. Clinically, carbon sulfide is a metabolic compound of certain therapeutic medications used to manage chronic alcoholism (Chalansonnet et al., 2018). Exposure to a high concentration of carbon sulfide compounds is associated with various health complications, including vascular problems, sensory disturbances, motor and neuropsychiatric issues. Multiple studies have shown that carbon sulfide exposure can cause distal axonopathy. For this reason, carbon sulfide is categorized as a neurotoxic substance.

According to Chalansonnet et al. (2018), carbon sulfide-induced low-frequency auditory problems and effects on general body posture have been identified in humans, especially those working in environments with unhealthy concentrations of carbon sulfide. For several decades, numerous studies have suggested that low-frequency noise is acutely detected by the vestibular receptors of the auditory system thus; both organic solvents like carbon sulfide and noise are capable of influencing body balance because organic solvents possess the capacity to potentiate the cochlea-traumatic sound effects of low-frequency noise. Various studies performed through pure-tone audiometry have shown approximately 66.7 % pervasiveness of auditory complications among workers exposed to carbon disulfide (Fuente and McPherson, 2006). However, only 6.6 % of these categories are associated with non-occupational factors. The study also showed that the proportion of individuals with occupational carbon disulfide ototoxicity increased significantly with age. People in the age group 18-29 recorded an increase of 52%, while those aged 50-60 recorded an 87% increase in hearing loss (Chalansonnet et al., 2018). These results indicate that neurotoxic implications can be found in individuals exposed to this organic solvent. Fuente and McPherson (2006) state that a considerable ratio of employees exposed to carbon disulfide for more than two decades obtained a protracted inter-peak expectancy for the ABR constituents III-V. Therefore, this type of organic solvent is also a significant contributor to hearing loss among workers. Thus, there is an urgent need for extensive research on the nature of the auditory issues associated with this type of solvent. This will assist in establishing various recommendations on how the exposure to this chemical can be reduced and highlight several rehabilitation procedures for those already dealing with hearing challenges stemming from this organic solvent.

2.1.3 Ototoxic effects of arsenic compounds

Hearing loss can be caused by exposure of human beings to Arsenic chemical elements. The chemical can get into the human body through drinking water hence posing a threat to human health. An arsenic chemical is linked with cancer and affects organs, kidneys, bladder, lung, liver, and prostate. In addition, when an individual has been exposed to the chemical compound, they are at risk of suffering from neurological diseases and cognitive impairment in kids and adults. To determine the levels of toxic elements in noninvasive, samples of urine, nails, and nails have been collected and tested. The illustrations are used to assess their relationship with hearing loss in human beings. Evaluation of the samples revealed a significant association of arsenic compound in fingernails with amplitude of alteration product otoacoustic emission that actively reflects in outer hair cells (Li et al., 2018). Arsenic presence in the nails is reliable evidence of arsenic-mediated hearing loss in human beings. Conversely, there is no direct relationship between the chemical compound levels in toenails and hearing levels. Some selected samples provide negative results regarding as presence; hence, they are not a reliable source of information concerning arsenic levels and hearing loss in humans.

In an experiment conducted, oral exposure to the chemical through drinking water was connected to hearing loss among young people despite smoking and age being the main contributors to hearing loss. Oral exposure to arsenic is the leading cause of health risks like carcinogenesis and cardiovascular diseases. According to Li et al., 2018, levels of toxic elements in the inner ears, which are sensory parts of the hearing, are determined to reveal the relationship with hearing loss. Therefore, arsenic toxic elements have been demonstrated to be connected to hearing loss among human beings. Intake of the chemical component through water or any other method has been causing different diseases and complications in human beings.

2.1.4 Ototoxic effects of toluene

Toluene is a compound found in electroplating, metal degreasing, paper coating, and pesticide manufacturing companies. The compound has been recognized to induce harm to the cochlea's outer hair cells (Fuente and McPherson, 2006). The harm triggered by this compound in its initial phases happens in the third row of the outer hair cells than towards the second and first row. The injury primarily affects the mid-frequency parts, differentiating the auditory induced by toluene from those detected with ototoxic drugs. A lower concentration of the compound does not prompt harm to the outer hair cells. Investigation revealed that decreased enzyme action in the mid-region of the cochlea affects hearing in animals.

Hearing loss among industrial workers is usually associated with noise, but organic solvents also play a critical role in hearing loss. Interaction between solvents and noise intensifies hearing loss in employees. Solvents primarily affect the auditory sensitivity in workers exposed to toluene (Chang et al., 2006). Toluene is the most widely used solvent in many industries; hence, hearing loss emanating from this compound is very high. For example, workers in a painting plant are at more risk for hearing loss due to noise and toluene. The threat of hearing impairment due to toluene exposure is more frequent compared to noise exposure.

It is proposed that the challenges of toluene on human hearing might depend on an amalgamation of ototoxicity and neurotoxicity. According to Fuente and McPherson (2006), brainstem auditory induced abilities in workers prone to an average toluene concentration of about 97ppm. Workers who are exposed to toluene obtain higher dormancy than those who are not exposed to the solvent. The blood concentration ratio affects the rate at which the compounds are absorbed into the bloodstream. The application of auditory brainstem response (ABR) to early recognize toluene-induced auditory harm should be taken into consideration by an audiologist. Auditory brainstem response is a test used to reveal a hearing abnormality. Workers exposed to a low solvent concentration obtain decreased wave amplitude of auditory aroused abilities. The low concentration of the solvent influences the extramedullary and high medullary sections of the auditory passageway. In addition, a low concentration of toluene prolongs latencies and reduces amplitudes in the p300 response.

2.1.5 Hearing loss due to occupational exposure to trichloroethylene

Workers exposed to trichloroethylene have high chances of experiencing sensor neural hearing loss linked with high audiometric frequencies. Most workers exposed to trichloroethylene experience auditory impairment more frequently. Vyskocil et al. (2008) suggest that the longer an employee is exposed to trichloroethylene, the more chances an individual will have abnormal audiograms. The detected hearing disorder exhibited signs of a decrease in the health condition of employees that are prone to trichloroethylene. Workers with long-term exposure to solvents are perceived to have abnormalities in speech, audiometry, and response.

Results on animals concerning hearing loss were performed on rats in which they were placed on different concentration rates of the compound. Rats were exposed to 1,000, 2,000, and 4,000ppm of trichloroethylene for six hours per day for five days. After which, the test was carried out on animals for auditory thresholds to 0.5 to 40 kHz tones. In another experiment following the same procedures, rats were exposed to 3500ppm of trichloroethylene. Auditory function was tested in a period of 5-8 weeks after the exposure period. The outcome revealed an increase in threshold in the mid-frequency tones (8 and 16 kHz) and higher or low tones. After some experiments were performed, it was revealed that trichloroethylene prompted hearing loss in mid-frequency. In addition, the cochlear potential was measured to determine the level of destruction by the compound. It was determined that cochlear histopathology revealed a loss of spiral ganglion cells in the middle turn. The statistics collected advocate that harm in auditory function can be connected to cochlear damage, and the spiral ganglion cell is the primary target by trichloroethylene. Possible inter-strain variances in trichloroethylene ototoxicity were evaluated by performing the test on fisher-344 rats. The outcome for the evaluation was the same as the other rats that exhibited mid-high frequency hearing harm in rats prone to different concentrations of trichloroethylene.

Ototoxic potential in people is not adequately described. It is challenging to assess disclosure to a single organic solvent because workers can contact different solvents daily. Therefore, it is difficult to determine the effects of a single compound on an individual. Trichloroethylene is associated with hearing damage in workers who are exposed to the solvents regularly. An experiment performed in rats revealed that a combination of exposure to the solvent and noise led to hearing loss (Fuente and McPherson, 2006). Trichloroethylene-induced ototoxicity might be imperfect in circumstances where work-related exposure reduces limit exceeded period. Despite all the experiments performed, there is a lack of proof on trichloroethylene-induced hearing harm in workers.

2.1.6 Aminoglycosides-induced ototoxicity

Some components of aminoglycosides like amikacin, gentamicin, neomycin, and netilmicin are applied to treat gram-negative microbial contaminations. In actual practice, the medical advantages of the agents are surpassed by the poisonousness they cause that comprises cochlear damage. For patients treated with an aminoglycoside, hearing loss incidences range between 27 to 33%. The hearing loss induced by aminoglycosides spread from high to low frequencies, primarily influenced by dose and duration of treatment.

According to Campo et al. (2013), after systematic use of the medicine, the antibiotics pass through the blood labyrinth obstruction at the stria vascular level and penetrate the cochlea. The antibiotics get to the perilymph hence the outer hair cell, and these parts are subtle to antibiotics. The antibiotics can remain in the hairs for some time, even after treatment. Due to the antibiotics taking long before they are cleared from the ear liquid, it causes an individual to experience some ear complications. The physician should employ aminoglycoside treatment to patients after a hospitalization because the worker could embark on having aminoglycoside compromised cochlea that might make them susceptible to noise. In addition, before an employee goes back to work, a company doctor should test every employee who has been hospitalized to determine the type of antibiotics used. Observing the ear serum aminoglycoside is not necessarily adequate to inhibit probable co-exposure; subsequently, the antibiotics spend much more time before they are completely cleared from the inner ear liquids than from the blood. It is essential to safeguard workers from unexpected prone to noise and aminoglycosides for some time after a worker is through with treatment (Huth, Ricci and Cheng, 2011).

The chemical gets through the outer hair cells emanating from the endolymph. The chemical does not result in lipid peroxidation; instead, they produce an aminoglycoside-iron complex that combines with polyphosphoinositides. Such reactions cause the generation and release of reactive oxygen species, increasing the cochlea membrane's permeability. According to Huth et al., 2011 damage caused by aminoglycosides cannot be reversed. The chemical damages the vestibular organ, and the modification of the chemical led to a change of ototoxic from the vestibular to the cochlea. Aminoglycoside has the capability of affecting both vestibular and auditory organs. The side effects are experienced within a short period after systematic administration. Symptoms of cochlea-ototoxicity may include hearing loss, while those of vestibular-ototoxicity may be associated with disequilibrium and dizziness.

These signs might not be detected until the acute phase of the illness is reached. Even though antibiotics have side effects, aminoglycosides remain the most used antibiotics. The application of antibiotics in the industrialized world is limited to severe infection. Aminoglycosides used in third-world countries have been popular because they are cheap and surpass expensive antibiotics with fewer side effects.

2.1.7 Ototoxicity of a mixture of organic solvents

Numerous proofs suggest that a mixture of organic solvents is ototoxic. Additionally, several studies on ototoxicity and occupational exposure to organic solvents have indicated a close correlation between noise and organic solvents on ototoxicity (Staudt, 2016). A combination of hearing loss and tinnitus is very detrimental to individuals' physical health and general well-being; this is because both hearing loss and tinnitus possess similar effects, which entail lifestyle alterations, emotional problems, and a decline in the general health of those dealing with such complications. Auditory issues like high frequency, permanent hearing loss, sensorineural, tinnitus, and irreversible hearing stem from the damages at cochlea nervous cells primarily induced occupational exposure to varied types of organic solvents (Staudt, 2016).

Research conducted by Occupational Health and Safety Administration (OSHA) has indicated that numerous employees working in the pharmaceutical, agricultural, textile, and paint industries are exposed to multiple types of organic solvents almost daily. However, OSHA also noticed that the degree of exposure to such chemical substances varies significantly with occupation. Therefore, the National Institute of Occupational Health and Safety (NIOSH) states guidelines that stipulate the recommended exposure limits (REL) for these chemicals. The REL is provided as the time-weight average of about 10 hours every day. Staudt (2016) states that organic solvents such as trichloroethylene, styrene, and benzene are viewed as probable work carcinogens thus; their recommended exposure limits are similarly comparable to no detectable exposure limits of proven carcinogenic chemicals.

A good number of studies conducted on the ototoxic effects of various organic compounds have suggested that exposure to the combination of several organic solvents significantly elevates the rate of hearing loss in workers in multiple industries. According to Fuente and McPherson (2006), the impacts of a group of organic solvents at specific frequencies can damage the inner ear's structures at a larger magnitude compared to exposure to extreme noise frequencies alone. Organic solvents ototoxicity has been realized in employees exposed to a mixture of xylene, carbon disulfide, toluene, ethanol, and ethyl acetate, among others (Estill et al., 2017). For instance, a study conducted by Sliwinska-Kowalska et al. (2017) suggested that a mixture of organic solvents such as xylene and ethyl acetate is the leading cause of auditory complications among exposed workers. In conformity with this finding, many other related studies have shown organic solvent-associated deficiency of the acoustic nervous structure in individuals exposed to a mixture of organic solvents. For instance, Fuente and McPherson (2006) suggest that employees are exposed to a combination of organic solvents and hazardous noise in various occupational environments; this indicates that occupational exposure to these chemicals in multiple industries is relatively high. For example, millions of employees working in the Chinese footwear industry are close to these organic substances. Therefore, these workers are at an increased risk of losing their hearing abilities or acquiring other auditory complications like tinnitus or partial deafness.

Moreover, Fuente and McPherson (2006) indicate that extensive research has been performed on the auditory effects of solvents such as styrene, xylene, and toluene. According to their findings, toluene is associated with a significant rise in the risk of ototoxicity among workers. Such outcomes indicate that organic solvents indeed possess ototoxic effects in humans.

2.2 Ototoxic Effects of a Combination of Organic Solvents and Hazardous Noise

Several studies have extensively considered the effects of both hazardous noise and organic solvents on the auditory system. In their research, Fuente and McPherson (2006) re-counted four circumstances of employees exposed to noise and organic solvents as having a significant level of sensorineural auditory complication compared to exposure to hazardous noise alone. Additionally, another study involving a larger group of participants to explore the degree of hearing loss among workers exposed to noise alone, a mixture of noise and organic substances, and non-exposed to either organic solvents or noise. The study outcome illustrated the auditory threshold and the upper rate range perimeter for auditory abilities for all the participants. Furthermore, the data denoted intangible variation in the hearing threshold between the three categories of participants.

Nonetheless, the upper-frequency rate parameter of the hearing was significantly decreased the category of participants exposed to both ototoxicity factors (Fuente and McPherson, 2006). Approximately 25 percent of workers in the group exposed to both noise and a mixture of noise and organic solvents recorded upper rate range hearing parameters beneath the 75^{th} percentile curvature for standard hearing participants. Such outcomes illustrate a collective effect of exposure to both hazardous noise and organic solvents. It is paramount to note that exposure to these agents of hearing loss was within the work-related exposure boundaries. Because auditory thresholds were consistent in both categories, it is, therefore, possible that valuation of upper-frequency rate parameter of hearing might be compelling compared to pure-tone threshold audiometry in the timely recognition of pointers of ototoxicity induced a combination of hazardous noise and organic solvents.

According to Nakhooda, Sartorius, and Govender (2019), there are numerous ototoxic effects of noise and solvents to the auditory system. These effects include damages to the essential structures of the cochlea, which entail sensory cells and nerve endings, destruction of the stria vascularis, which is a vital liquid that produces cell layers situated on the exterior hedge of the cochlea duct. Furthermore, these factors contribute to the demolition of the spiral ganglion structure, damage to the vestibular system, restro-cochlear destruction, and finally, the destruction of both pillar and either system of the Corti. This shows that both noise and organic solvents' combined impact on the auditory structure possesses equivalent pathophysiology like hazardous noise-induced hearing loss. However, Nakhooda et al. (2019) state a massive issue in labelling the mutual effects of these ototoxicity agents since it is not accurate which exact factor causes auditory malfunction. Therefore, it is not easy to identify if organic solvent exposure, noise exposure, or a mixture of the two elements are the primary source of the auditory issues reported by millions of workers around the globe. As a result, robust research endeavors need to be conducted on this front to assist in vital information that can significantly contribute to formulating occupational health policies and regulation amendments (Nakhooda et al., 2019).

2.3 Auditory Complications due to Pharmaceutical Drugs

Several drugs are associated with numerous side effects, including tinnitus and partial or permanent hearing loss among workers. According to the study conducted by the American Speech-Language-Hearing Association (ASHA), there are over 200 pharmaceutical medications associated with auditory challenges and other body posture ailments (Victory, 2020). Such drugs form a significant portion of ototoxic factors within various work environments. Victory (2020) suggests that the extent of auditory issues such as deafness and tinnitus primarily rely on the type of medication, the prescription, and how long an individual is exposed to such drugs. In totality, the peril of ototoxicity of such drugs is closely related to the frequency of exposure or the quantity present within an individual's body. Some of these pharmaceutical medications include hydroxychloroquine, antibiotics, chemotherapy drugs, and certain painkillers. American Academy of Audiology ascertained that drugs like chloroquine are a significant contributor to temporary impairment of hearing ability and tinnitus in humans, primarily when used for a prolonged period. However, some individuals have been noticed to establish auditory issues within a few days of using hydroxychloroquine drugs. However, the dangers of ototoxicity due to antibiotics are predominantly high in newborns, and therefore, clinicians must take adequate precautions before administering such drugs.

The survey conducted by the National Health and Nutrition Examination found that almost two-thirds of the women aged 60 years and above in the U.S. have hearing problems (Lin et al., 2016). Hearing loss has been attributed to various antibiotic drugs such as aspirins, acetaminophen, and nonsteroidal anti-inflammatory medications. Lin et al. (2016) indicate that these types of antibiotics might be ototoxic, primarily when used for protracted periods. These drugs cause severe damage to the external hair cells, minimize cochlea supply and cyclooxygenase reticence. As a result, the exhaustion of cochlea glutathione by such drugs increases the vulnerability of the cochlea to destruction stemming from hazardous noise levels. In addition, a study performed on a group of women suggested that frequent use of antibiotics such as ibuprofen is linked to greater chances of auditory complications like hearing loss and tinnitus (Lin et al., 2016).

2.4 Exposure to Firearms or Explosives Noise in Occupational Settings

Chronic high-intensity exposure to noise is a joint environmental problem in many societies. These can lead to hearing harm and tinnitus that might lead an individual to develop health problems like cardiovascular, sleeping problems, and diabetes. People might be exposed to a short burst of solid sound that can permanently or temporarily lead to hearing problems. According to Bhatt et al. (2017), the examination done on animals has delivered an exceptional understanding of the impacts of noise acquaintance to the auditory system, comprising critical harm of afferent synaptic terminals trailed by the deterioration of the cochlear nerve in deferred style. In addition, the subsequent damage of auditory neurons has been advocated to subsidize hearing problems in stimulating listening environment hyperacusis and tinnitus. Despite occupational noise being the main foundation of chronic high-intensity noise exposure, there has been a collective suggestion of medical relevant contribution from other sources. In addition, music has been linked to raising the risk of noise-induced hearing impairment. Other reasons can cause a hearing problem; for example, sporting events, power tools, and concerts may permanently influence hearing.

Noise-induced hearing harm is perceived to be one of the joint occupational health anxieties in society. This is because both the chronic-high intensity and intense impulse noise may negatively affect an individual hearing. Despite both types of noise being destructive, some people believe that impulse might be more damaging to hearing than continuous noise. Challenges of induced noise can be aggravated in connection to age-related threshold shift. The body goes through collective harm from impulse noise and chronic noise exposure, leading to clinically substantial hearing harm over a short period. According to Bhatt et al. (2017), occupational g individuals are at high risk of hearing problems, including farmers, construction workers, and military workers.

The U.S. Occupational Safety and Health Administration established rules and standards that workers must consider while at work. The laws and regulations protect the workers from harmful effects caused by acoustic exposure to noise (Bhatt et al., 2017). Workers may request a limit of hours that they feel is appropriate for them to take some moment outside from the noisy environment. Some workers might opt to use hearing protection in their occupational setting.

Two devices are used to measure noise exposure which is the sound level meter and dosimeter. The sound level meter only offers a sudden measure of noise levels to very cultured instruments capable of logging measurements over time and offering simple statistical steps. A dosimeter is used to measure noise levels over an extended time (Bhatt et al., 2017). The devices can be classified into type one and type two, in which type one instruments are applied to measure noise in a laboratory setting, and type two is used to measure noise when an individual is in the field. Due to technological advancement, people have started using phone applications to measure noise exposure.

Conversely, continuous noise exposure, impulse noise exposure may lead to noise-induced hearing problems. Impulse noise is a sudden intense noise caused mainly by explosions or even high speed or energetic impact. A hearing problem can either be conductive in which sound waves are attenuated or changed during their course of passing through the outer and middle ear. Hearing loss is characterized by decreased hearing sensitivity. Loud noise can generate physical and emotional stress, reduce productivity, and inhibit communication and attentiveness (Bhatt et al., 2017). In addition, impulse noise can lead to accidents during working; hence, it is essential to minimize noise and protect the employees from loud noise.

2.5 Ototoxicity due to Occupational Exposure to Heavy Metals

Being in close proximity to various chemical substances has been proven by numerous studies to cause occupational chemical-induced auditory challenges like hearing loss and tinnitus. For many years, most studies on occupational ototoxicity have predominantly focused on organic solvent-induced hearing loss and other related auditory impairments. Nonetheless, several chemicals like heavy metals have also been identified as ototoxic causes (Castellanos and Fuente, 2016). Various heavy metal substances such as lead and mercury are found in a work situation in several forms. Therefore, workers are highly susceptible to being exposed to one or all of these heavy metals during their working hours. Consequently, humans develop auditory structure impairments because of the adverse side effects of such metallic substances in their body systems.

2.5.1 Effects of mercury on the human auditory structure

Multiple work environments are characterized by mercury-containing elements such as metallic and organic substances. These compounds can be ingested through inhalation or consuming contaminated water or foodstuffs. Industries like gold mines, industrial lamp factories, and other firms involved in gold-mercury or silver-mercury exploitation are primary sources of occupational mercury exposure. Moreover, mercury is a stable amalgam when mixed with other metals such as gold or silver that has been applied in dental treatment such as a dental filling. All these sources of mercury are a significant threat to human health since prolonged exposure to substances containing mercury has been known to cause numerous health complications, including auditory challenges like tinnitus and hearing loss.

According to Castellanos and Fuente (2016), research conducted on 138 employees exposed to mercury in a particular industry contrasts with a control group of 151 employees lacking historical exposure to mercury. The control category was matched with exposed participants regarding age, education level, income, and residence. The study's outcome suggested that the mercury-exposed type indicated a higher auditory structure complication pervasiveness than the non-exposed category. In another study conducted by Hoshino et al. (2012) noted that occupational exposure to metallic compounds containing mercury is ototoxic in that mercury induces both peripheral and central hearing loss among exposed workers. Additionally, these studies showed that being in contact with mercury can cause irreversible distractions to the main auditory structure. However, Hoshino et al. (2012) stated that gauging mercury intensities with biomarkers could not forecast the connection between the severity of mercury poisoning and the level of distractions it causes to the auditory system. Pacheco-Ferreira et al. (2015) also showed an insignificant relationship between the inhibitory impact of the medial olivocochlear system (MOCS), the quantity of mercury in the environment, and ages. Thus, the pathophysiological effects of acute and prolonged mercury exposure might be restrained and nonspecific, and the results can last for an extended period. As such, the auditory effects of mercury exposure must be closely monitored.

2.5.2 Occupational exposure to lead and hearing loss

Despite lead being phased out by gasoline, exposure to environmental lead is reduced, leading to decreased blood lead accumulation in adults. Lead toxicity has significant public health apprehension mostly on older adults due to exposure to lead for a long time that accumulates in the bones and stays there for long. According to Park et al. (2010), with the evolution of the period, lead can be organized beginning from the bone into blood circulation, leading to the destruction of the nervous system and the cardiovascular system. Current analyses have revealed that increasing lead contact is related to age-linked diseases like an intellectual failure, growth-related cataracts, high blood pressure, and cardiovascular mortality.

Exposure to lead for a long time increases the risk of hearing loss, and it is the primary chronic health problem experienced by older individuals. Research reveals that lead contact, even in small amounts, may cause impairment to the inner ear receptor cells and the auditory neuronal purpose (Park et al., 2010). Studies have revealed that employees exposed to lead while working experience hearing loss and impaired hearing capacity. In the current generation of hearing, the loss is one of the significant philosophical recurrent restricting problems mature adults can undergo. Research proclaims that about 35 million individuals of nearly 18 years have hearing difficulties in the U.S. The primary issue of hearing loss is that it reduces life quality, and individuals suffering from the problem have other underlying issues like social and physical concerns (Park et al., 2010).

Global Hearing loss frequency currently stands at 5% among the adult population. This figure increases rapidly to around 30% as an individual gets old (Park et al., 2010). Hearing loss can cause negative consequences like troubled communication, frustrations, and feeling of being neglected. Environmental cadmium and lead elements are the most significant collective harmful poisonous metals that cause diseases. These substances can cause harm to parts of the ear and the nervous structure of the inner ear. Lead exposure emanates from solar panels, pigments, and the production of batteries. The two compounds can lead to reduced blood circulation and lipid peroxidation in the cochlea; Lead contact might lead to degradation of receptor cells in the internal compartments of the ear, whereas cadmium encourages apoptosis of receptors cells and the alteration of their arrangement. According to Wang et al. (2020), scientific research has identified the valuable outcome of lead or cadmium on an individual's psychological health. Therefore, learning about the impact of heavy metals has become necessary in the field of occupation and the public because it determines the level of damage caused and how it can be controlled.

Exposure to lead and lead products is obstinate environmental contamination primarily found in the water, soil, and air. Lead accumulates in these areas and is later engrossed by humans through ingestion or inhalation. Contact with even small amounts of lead can result in antagonistic harm in different body tissues and organs. Contact to low lead levels during the growth stage reduces the manifestation of the voltage-dependent anion passage protein, disrupting the monoaminergic arrangement in the acoustic brainstem. In addition, lead exposure causes disturbed cochlear blood-labyrinth inhibition and leads to vestibular infection.

Usually, oxidative stress plays a vital function in auditory infection because it triggers cochlear cell death passageways, causing a hearing problem linked with old age exposure to organic and ototoxic solvents. Oxidative stress-induced harms have been noticed in different areas of the cochlea. Lead exposure has been identified to result in oxidative damage in other muscles and structures through prompting lipid peroxidation and affecting the antioxidants protection system. According to Daniel et al. (2018), lead-induced oxidative harm is perceived to affect the nervous system. Exposure to ototoxic elements is widespread in daily activities, and an individual cannot evade them. When an individual is exposed to combined sub-toxic levels might contain additive or synergistic relations, leading to auditory dysfunction.

Research has revealed that concurrent contact to lead and noise has been associated with inducing hearing loss and a preservative effect on the auditory system. Pooled contact with noise and lead is perceived to have a preservative result on the hearing sense of oxidative stress that plays a pivotal role in facilitating noise-induced cochlear cell damage, which is described to enable intractable health problems of lead. Regular contact to reasonable lead amounts of acetate in water prompts a substantial modification in the hearing threshold. Chemicals and non-chemical agents trigger the cochlear oxidative stress pathways, which result in auditory dysfunction. In an experiment, variations in the oxidative stress genes cause contact to changes in the appearance of numerous apoptotic genes in the cochlea. If an individual is simultaneously exposed to lead, it causes amplified exposure to noise-induced hearing loss

3.0 Methodology

Extensive research was conducted on various internet databases to obtain relevant peer-reviewed publications concerning the effects of ototoxic organic solvents and occupational exposure to humans. The relevant articles mainly were obtained from publication databases like PubMed and Google Scholar. Ototoxic organic solvents such as Toluene, Styrene, Mercury, Aminoglycosides, Lead, and a mixture of such solvents were used as the keywords in obtaining the necessary publications (Morata et al. 2017). Furthermore, words and statements such as ototoxicity, occupational induced auditory complications, noise-induced hearing loss, and auditory challenges due to exposure to organic solvents among various workers were used to widen the scope of the research.

However, time parameters were never reflected during the investigation. The research was able to yield 37 peer-reviewed publications on the ototoxic effects of organic solvents on humans. All the articles were eligible for the study, and therefore, they were all incorporated into the research. To guarantee the accuracy and authenticity of the publications, the scope of the research articles was constricted to epidemiological studies on humans. Therefore, studies involving animals were excluded.

The publications were further vetted for inclusion by looking at which ototoxic organic solvent they focused on. Therefore, the journals were eligible for inclusion if they discussed the effects of ototoxic exposure of one or more organic solvents of interest and auditory complications among workers as the health outcome (Hemmativaghef, 2020).

Consequently, the publications were reviewed to discover any association between occupational exposure to such organic solvents and auditory impairments in humans. Once a noticeable relationship was determined, occupational exposure heights were examined to ascertain if the concentrations related to amplified peril of auditory impairment could be recognized. These risks included the No Observed Adverse Effect Level (NOAEL) and Lowest Observed Adverse Effect Level (LOAEL) (Hemmativaghef, 2020). NOAEL is the extreme occupational ototoxic exposure height. There is a lack of statistically substantial rises in the frequency or brutality of the ototoxicity impacts between exposure categories and their related controls (Hemmativaghef, 2020). On the other hand, LOAEL denotes the minimal occupational exposure heights. There are statistically essential rises in the severity and frequency of the adverse impacts of ototoxic toxins among the categories exposed to organic solvents and their appropriate control groups.

The author also conducted a cross-jurisdictional assessment between U.S, Canada, Australia, and United Kingdom occupational health and safety regulations. The cross-jurisdictional assessment was performed in these countries since they are the leading industrialized nations with high per capita income and advanced occupational health and safety regulation structures. The various regulations were identified through multiple online legislation databases such as the International Labor Organization (ILO) online portal. The main words used for searching the legislations and guidelines included ototoxicity and organic solvents-induced hearing loss. The primary objective was to discover how various jurisdictions manage non-auditory complications such as tinnitus or partial or permanent deafness as occupational exposure. Moreover, the author sought to identify multiple recommendations and necessary control measures that these jurisdictions have put forward to tackle the effects of ototoxic toxins and occupational exposure to organic solvents in humans (Hemmativaghef, 2020).

4.0 Results and Discussion

After conducting a comprehensive and critical review of the selected publications, the results were as follows.

4.1 Arsenic Compounds

According to several publications selected for this research, occupational exposure to arsenic compounds is a severe threat to the auditory system (Kesici, 2016). This is because significant quantities of arsenic compounds occur in numerous work-related environments thus; many people are exposed to it. For instance, a study conducted by Kesici (2016) indicates that over 100 million individuals work in industries characterized by chronic levels of arsenic compounds. Because of such exposure levels, many people are dealing with arsenic-induced auditory complications such as hearing loss or tinnitus. Occupational exposure to arsenic compounds predominantly occurs through dermal, oral, respiration routes or both (Kesici, 2016). Some of the leading factories associated with chronic levels of arsenic compounds include mining firms, melting factories, and agricultural firms where products such as fertilizers and pesticides are manufactured. Additionally, these compounds occur in divergent forms and different environments. Therefore, assessing the level of occupational exposure to arsenic elements might be quite sophisticated. Other heavy metals such as fluoride and cadmium might also be present in the same environment (Kesici, 2016). Many publications selected for this research showed that exposure to arsenic compounds is highly ototoxic to humans, especially those working in firms dealing with the production of heavy metals. For instance, sensorineural auditory impairment was indicated in workers exposed to arsenic compounds (Kesici, 2016).

4.2 Aminoglycosides

These substances entail chemicals such as tobramycin, gentamicin, kanamycin, and amikacin. These products are examples of an elaborate group of antibiotics used to manage alleged or established severe infections in humans and long-term treatment of recurrent respiratory ailments in cystic fibrosis and acute tuberculosis conditions (Kros and Steyger, 2018). The initial ototoxicity of these substances was first observed by applying streptomycin to treat various types of infections in humans. However, recent studies have shown that novel types of aminoglycosides have different levels of auditory toxicity. The possibilities of the occurrence of acoustic issues such as deafness and tinnitus due to exposure to aminoglycosides vary significantly because of the divergence in exposure levels and periods. Nonetheless, auditory toxicity can occur in almost 60% of the total individuals exposed to such chemicals (Kros and Steyger, 2018). However, the ototoxicity of aminoglycosides is potentiated by instantaneous occupational exposure to hazardous noise at quantities capable of causing minimal or severe auditory impairment (Steyger, 2009). Therefore, eliminating incidences of extreme noise before using aminoglycosides is acutely critical in examining the accurateness of the contribution of aminoglycosides to the auditory challenges among individuals exposed to such substances. (Steyger, 2009), found that moderate noise levels potentiate aminoglycosides-induced ototoxicity encompassing higher levels of long-lasting acoustic threshold changes. Contrarily, subtoxic heights of organic solvents-induced hearing loss at noise levels are capable of causing insignificant or no hearing issues when given alone.

4.3 Trichloroethylene

Vyskocil et al. (2008), in their study, found that exposure to trichloroethylene induces hearing loss. In their study, workers exposed to trichloroethylene reported severe auditory dysfunctions encompassing both deafness and tinnitus. The acoustic challenges were suggested to stem from severe damage to the auditory nerves due to occupational exposure to trichloroethylene. In a cross-sectional study involving 40 trichloroethylene-exposed individuals, 26 individuals experienced bilateral high-frequency sensorineural auditory impairment. The study also indicated that the degree of severity of the auditory dysfunction is directly linked with the period of exposure. For instance, individuals exposed for a prolonged period experienced severe acoustical challenges compared to those exposed for a short period. Therefore, the longer an individual is exposed to trichloroethylene, the higher the likelihood of them accruing abnormal audiograms.

Additionally, the study's outcomes conducted by Vyskocil et al. (2008), Fuente, and McPherson, B. (2006) indicated that identified auditory disorders were early symptoms of deteriorating health conditions of employees exposed to organic solvents, especially trichloroethylene. For instance, employees with prolonged occupational exposure (5-20 years) to organic solvents like trichloroethylene exhibited various abnormalities such as distorted speech audiometry and cortical reactions to frequency glide. Despite these results, it is pretty tricky to thoroughly assess the ototoxicity of a particular organic solvent since employees are customarily exposed to divergent forms of chemicals in their work environments. Moreover, it is also challenging to pinpoint employees with essentially direct exposures to a singular and specific organic solvent. Therefore, to adequately understand the ototoxicity of trichloroethylene, it is essential to exclude other relevant factors like hazardous noise and other organic chemicals within the work environment. Nonetheless, this might be difficult since all these factors characterize all most all occupational areas.

4.4 Styrene

Various selected publications for this research have closely associated work-related exposure to styrene with heightened possibilities of acquiring various auditory complications. However, the exact nature or sites of damage within the auditory system due to styrene remain elusive to many researchers. Sliwinska-Kowalska et al. (2020) conducted a study to examine the probable adverse ototoxic consequences of occupational exposure to styrene on the human auditory system. The authors evaluated the hearing capacities of 98 styrene exposed male employees of specific glass industries. The investigation was conducted bilaterally by applying pure-tone audiometry, auditory brainstem response (ABR), and distortion product otoacoustic emissions (DPOAEs). Their research contrasted their outcomes with a collection of workers exposed to hazardous noise and a group of white-collar employees exposed to neither organic solvents nor unsafe noise.

Consequently, their results suggest that occupational exposure to styrene is significantly allied with lower DPOAE profusions and low pure-tone thresholds than the control category participants. Additionally, the authors also obtained similar outcomes among participants that were exposed to hazardous noise. Additional examination using wave V latency indicated that subjects exposed to styrene had petite latencies than predicted. These outcomes suggest that prolonged industrial contact with organic solvents such as styrene at moderate quantities can inflict various cochlea-ototoxic conditions. Therefore, DPOAEs might be a very effective auditory ototoxicity tool for employees exposed to both intermediate and extreme levels of styrene (Sliwinska-Kowalska et al., 2020).

4.5 Lead

Based on results collected from different analyses on bone lead measurement and audiometric tests carried out on persons of different ages, it was concluded that they were highly correlated with age. This outcome was evident in individuals with varying health conditions like older age, higher occupational noise exposure, smoking disorders, and noise notch. According to Park et al. (2010), lead in bones is significantly linked with elevations in the hearing threshold at a different speed. The magnitude associated with hearing loss was affected by various factors like race, BMI, hypertension and history of diabetes. When the occupational noise exposure is controlled, noise notch the level of lead in bones remained substantial predictors of poorer hearing threshold. An experiment was performed to decide whether the association between hearing loss and bone lead levels was modified by occupational noise exposure. Experiments showed that a high lead level in the bones raises the rate of elevation of the hearing threshold. Cumulative lead contact and is significantly linked with a poor hearing threshold.

Different groups of individuals showed the difference in lifestyles like alcohol consumption, smoking and vegetable and fruit intake significantly affected hearing capability. According to Wang et al. (2020), different groups of participants in the experiment showed variations in hearing threshold. It was revealed that workplace noise was significantly linked with hearing loss, but entertainment noise was not linked with hearing damage. The relationship of the contributor's blood cadmium who took part in the evaluation and lead levels revealed hearing loss. The relationship between blood lead and cadmium and hearing damage was evaluated after altering different conditions. In addition, blood lead exhibited no relation with hearing impairment once regulating workplace noise contact. The experiment revealed the harmful results of lead and cadmium on hearing damage.

To measure the effect of lead contact on the auditory system, an assessment was carried out to determine the auditory brainstem response. The data collected afterwards revealed that chronic exposure designated that contact with lead effects 8-12dB changes in the hearing threshold. The relative evaluation of the hearing threshold shift caused by lead contact showed that contact suggestively raised the hearing threshold. The collected results showed that persistent lead contact leads to crucial practical deficiency in the auditory structure even at a modest chronic level.

The examination of variance expression of oxidative stress genes in the cochlea was done using beleaguered PCR arrays. The results showed that either of the genetic factors was upregulated or downregulated in the cochlea due to lead contact. Through experiments on the effects of oxidative stress, it was revealed that lead-induced ototoxicity caused hearing loss.

The influence of concurrent contact to lead on noise-induced hearing loss was analyzed by determining the hearing brainstem response. Experiments revealed that regular contact to a reduced noise level prompted 11-15 dB lasting change in hearing threshold. Relative evaluation of hearing threshold changes prompted through joint noise, and lead contact with secluded contact to noise revealed that concurrent contact with lead suggestively raised the noise-induced change in the hearing threshold. The analysis revealed that lasting lead contact intensifies noise-induced hearing loss. The association of ecological and work-related contact to lead has appropriately been recognized. Both chemicals and non-chemical causes lead to auditory infection triggering the cochlea oxidative stress ways.

4.6 Toluene and Noise

After evaluation, there was not much difference in age among the individuals used in the analysis. Some individuals used hearing protection and were used as a control experiment. The occurrence of hearing loss was more extraordinary in individuals exposed to noise and toluene. The event of hearing damage reduced approximately when noise and toluene conditions were altered. The level of hearing loss increased as the noise and toluene level increased while other factors remained constant (Fuente and McPherson, 2006). Poor aural faculty thresholds were experiential at low and high frequencies. At low frequency, workers exposed to noise and toluene possessed a poor point than those who encountered noise only.

The experiment involved several conditions like smoking tobacco. After control of smoking, age, hearing protectors and alcohol drinking demonstrated an increased hearing loss to workers exposed to all the requirements. Therefore, the rate of hearing loss is determined by a combination of factors in which, if they are availed at the same time, high chances of experiencing hearing loss increases.

Toluene intensity and exposure duration play a critical role in the manifestation of hearing loss. The results collected showed that each factor interaction led to mixed results due to dissimilarities in analysis in an experiment. Noise intensity showed a significant impact on the hearing intensity, and different conditions revealed different outcomes. The concentration of toluene contact in ambient air, the development of biological monitoring, and noise concentration did not contribute expressively to the conclusion of auditory harm. The primary exposure variables were the current noise contact for different age groups, and the analysis was repeated on different ages for the logistic regression.

4.7 Firearms or Explosives Noise in Occupational Settings

The Results of various publications showed different sources of noise that could lead to hearing problems. According to Bhatt et al. 2017, while at work, victims of the hearing problem revealed that very loud sound contact in a long period caused hearing loss. When asked about the use of firearms, many admitted to having fired a gun in their life. However, some individuals use firearms for recreational purposes. Many of the respondents used hearing protection while they were firing, while others did not use it.

Taking more time in a noisy area more than ten times in a year for recreational was examined. The more an individual spends more time in a nosy environment, the more chances of experiencing hearing loss increase. An acoustic signal influences the ear through its total time being longer. The movement that passes through the ear can also be categorized by operational duration and the restrictions of a solitary impulse noise determined by the number of sound signals that reach the ear. An individual can be exposed to about 20,000 auditory incentives in a year who always shoot for recreation. The most significant problem is that an individual can be exposed to high noise levels in that some people practice shooting in groups. This result reveals differences in the exposure to permanent noise and impulse noise of trainers and trainee shooters. The effects of loud sounds depend on how the inner year reacts to the incoming sound and how the defense mechanism responds.

4.8 Carbon Disulfide

Morata et al. (1994) confirmed that occupational exposure to carbon disulfide induces both severe and chronic auditory damage. However, the effects of this substance on the acoustic structure are nonspecific. Thus, making individual diagnosis an issue of possibility relies on other aspects such as validation of exposure, elimination of other health conditions, and the occurrence of various indicators of auditory challenges like tinnitus and hearing loss. A study by Morata et al. (1994) was performed to define the involvement, which otoneurologic and audiologic examinations could induce to the authentication of auditory intoxication of carbon disulfide. The selected participants were subjected to a varied concentration of carbon disulfide. The outcome of the otoneurologic and aural examination suggested a significant rise in the frequencies of pathological auditory indications and sensorineural deafness. However, zero carbon disulfide exposed participants reported minimal pathological vestibular manifestations and sensorineural deafness (Morata et al., 1994). These outcomes indicate that occupational exposure to carbon disulfide induces auditory complications. However, the ototoxicity effects of this chemical are more pronounced when both hazardous and divergent types of organic solvents characterize the work environment. Thus, extensive research on the personal effects of carbon disulfide needs to be done to discover the significance of its threats to the workers without other contributing factors like hazardous noise and heavy metals.

4.9 Combination of Heavy metals and Hazardous Noise

A study conducted by Choi and Kim (2014) demonstrated a significant relationship between occupational exposure to hazardous noise plus heavy metals with high levels of hearing loss among workers from different industries. Additionally, the study outcomes also indicated that people working in factories that deal with heavy metal products such as lead, mercury, and cobalt are characterized by elevated perils of auditory impairments. The interaction between heavy metals and hazardous noise extensively damage various auditory structures such as vestibular cells and cochlea cells, thus leading to multiple types of acoustic issues like tinnitus or deafness. Choi and Kim (2014) acknowledged that occupational-related auditory challenges like hearing loss are one of the most prominent occupational risks that many workers all over the globe are currently dealing with. Hazardous noise is a major contributing factor to work-related hearing loss. Therefore, numerous studies have consistently advocated regulating the degree of noise exposure to scaling down the prevalence of occupational-related auditory complications (Choi and Kim, 2014). With this situation in mind, many nations around the globe have come up with divergent national strategies aimed at monitoring and regulating noise levels in their respective factories. However, it is has been very cumbersome to manage or minimize noise exposure in several industries. Thus, pinpointing vulnerability-associated dynamics in concurrence with the avoidance of noise, which is the primary factor, is crucial for the effective management of occupational risks associated with noise exposure.

Regardless of various biological shreds of evidence of the ototoxic effects of heavy-industrial metals put forward by previous studies, most occupational hearing loss incidences primarily stem from exposure to extreme levels of noise (Choi and Kim, 2014). This means that heavy metals and other related factors such as organic solvents play an insignificant role in causing auditory challenges among workers. The pronounced impacts of hazardous noise in most occupational environments might authenticate why most prior studies suggest such outcomes. Nonetheless, some recent studies have associated various heavy metals especially lead and cadmium, with hearing loss. It is acutely paramount to note that such results were only recorded in individuals not exposed to hazardous noise but in those exposed to low or medium noise levels (Choi and Kim, 2014). Therefore, such results indicate that the noticed auditory risks associated with exposure to heavy metals might be degraded by significant acoustic risks related to exposure to hazardous noise. For instance, in line with prior studies, the current sensitivity analysis stratified according to noise levels suggested that heavy metal exposure severely influences hearing thresholds in workers exposed to medium noise levels.

Nevertheless, the same study found no severe metal exposure effects in workers exposed to loud noise (Choi and Kim, 2014). This observation further suggests that hazardous noise is the chief contributor to hearing loss among workers. At the same time, heavy metals only have additive ototoxic effects, especially in an occupational setting with low-noise levels.

4.10 Heavy Metals and Organic Solvents

In terms of occupational exposure to both heavy metals and organic solvents, most of the selected publications showed that the occupationally relevant exposures to these substances might be ototoxic to the auditory structure. Nonetheless, for most situations where the possibility of ototoxicity was acknowledged, there was insufficient toxicological information about the degree of auditory impairment due to occupational exposure to heavy metals and organic solvents alone. Numerous types of examinations such as pure-tone audiometry, reflex modification audiometry, immitancemetry, and auditory nerve compound action potential test have been used to investigate the effects of occupational exposure to these substances. Accordingly, various methodologies have also been used to evaluate the influence of chemical exposures. In several reported experiments involving g human beings, the chemical exposure history was examined through random queries in conjunction with scanty exposure accounts. About heavy metals, exposure was concerned via biological monitoring. All the publications signified that noise exposure is critical in determining the severity of auditory impairments due to chemical exposure among workers.

5.0 Conclusion and Recommendations

It is accurate to conclude that synchronized occupational exposure to organic solvents and heavy metals, especially in work environments characterized with extreme noise frequencies, causes auditory impairments like hearing loss and tinnitus. According to the existing works of literature, there is a detailed record of simultaneous chronic occupational exposure to organic solvents and heavy metals such as styrene, carbon disulfide, toluene, mercury, arsenic compounds, and hazardous noise. The results of the selected publications were able to ascertain the degree of ototoxicity of these chemicals to the auditory structures of human beings working in different factories. For instance, Morata et al. (1994) confirmed that occupational exposure to carbon disulfide induces both severe and chronic auditory damage. Similarly, Castellanos and Fuente (2016) research conducted on 138 employees exposed to mercury in a particular industry contrasts with a control group of 151 employees lacking historical exposure to mercury indicated a high rate of auditory complications in the exposed group compared to the control group. However, such deductions are made dependent on the workers' accounts since most firms shy away from availing information about the level of organic solvent concentration and the frequency of exposure among their workers.

Since most of the selected publications have reported many auditory issues due to organic solvent exposure, elaborate strategies must be put in place to help mitigate the situation.

The human auditory system is susceptible to solvent exposure. Therefore, even minimal exposure to low levels of ototoxic solvent can lead to hearing loss. Some preventive conditions of coming into contact with the solvents can be a problem because individuals are sometimes unaware that they are exposed to the solvents. Millions of workers are exposed to noise in workplaces daily where noise cannot be controlled. Evaluation has revealed that exposure to ototoxic auditory problems despite coming into contact with a loud noise. Substances like pesticides, solvents, and pharmaceuticals comprise ototoxic chemicals and cause negative impacts on the ear functioning, causing hearing problems.

Employers have to provide necessary health and safety information that their employees can use to avoid contact with chemicals that can lead to hearing loss. Employees should be provided with information that they are working in an environment that can cause hearing problems. By doing so, individuals can make appropriate decisions to continue working in the hazardous environment or choose to quit the job. Controlling exposure can be performed in many ways; for example, if a company uses toxic chemicals, it can shift and use less harmful chemicals to reduce exposure to ototoxic compounds. Eliminating toxic chemicals from the workplace is impossible because the substances are the primary raw materials and cannot be eliminated. Industries can use engineering control like isolation and enclosure to regulate exposure to ototoxic and noise. The motive of ototoxic control may decrease adverse health effects that can occur in the future. There is some administrative control to eliminate the unnecessary cause of noise or exposure to the ototoxic contact or operating noisy equipment when many employees are around.

Styrene exposure can come from using unsaturated polyester; employees are often exposed to evaporating styrene monomer. There are adverse health problems caused by styrene exposure, including the nose, lungs, and throat irritation, and causes hearing loss. Prolonged exposure to the chemical affects brain functioning and later can lead to death. Most legislation demand that the accountability for determining and monitoring workplace concentration of chemicals lies in the employer's hands. Workplace exposure can be determined by using commercially available. Manufactures can respond appropriately to decrease exposure and ensure that all industries using styrene chemicals ensure compliance with laid down safety measures (Pleban et al., 2017). To ensure control of styrene vapor, workplace ventilation is essential because the vapor is produced close to the molding operation; hence it is vital to remove the air as soon as possible. In addition to ventilation, personal protective after process-related measures and engineering regulations like workplace ventilation have been adequately evaluated and implemented.

Arsenic compounds get into the human body through different pathways. Therefore, controlling the intake of arsenic compounds can take other methods depending on how it gets into the human body. The primary information of an arsenic compound is through drinking water. To prevent the widespread arsenic compounds is to provide safe water for drinking, irrigation, and water used to prepare food (Kesici, 2016). There are different ways to reduce arsenic compounds in water, like substituting high arsenic sources like groundwater with low-arsenic. People can use alternative sources of water like rainwater or treated surface water. Suppose water is revealed to contain high levels of the arsenic compound. In that case, it is essential to discriminate such sources and use water that has low levels of arsenic compounds, water that contains high levels of the arsenic compound can be blended with water that contains low levels of arsenic compound to get sufficient water that includes an appropriate level that cannot have significant effects. Controlling the arsenic compound in water can also be done by installing arsenic removal systems that can be centralized or domestic. The arsenic residue collected should be appropriately disposed of to prevent it from returning to water sources or contaminating human food (Kesici, 2016). The technological advancement that can remove arsenic from water includes ion exchange, coagulation-precipitation, and membrane techniques. Therefore, community members need to be aware of the risks associated with exposure to arsenic compounds. In addition, the high-risk population should constantly be monitored and offered the necessary assistance required to control arsenic contamination.

Toluene is a colorless liquid that evaporates upon exposure to air at room temperature, and its presence can be detected by its sharp, sweet odor. Employees are exposed to toluene through breathing, swallowing, or swallowing it. This type of contact with the chemical makes employees immediately sick or causes hearing effects over time. To ensure the safety of employees, it is essential to ensure proper ventilation and adequate safety precautions. OSHA exposure limits for the chemical have been set to prevent the effects of long time exposure on employees' bodies. Wearing protective gears can be the primary protection against coming into contact with the chemical. In addition, people can remove toluene and other VOCs in the air by use of air purifiers; also, carbon filters can be used, but they should be regularly be changed.

Mercury is ingested and can cause hearing problems; hence, there are ways to reduce mercury exposure. The methods can also include attempts to decrease the amount of mercury in the environment. Mercury can accumulate in the human body by eating fish due to goldmines occurring near water bodies. When people consume fish, it leads to an increased accumulation of mercury in people’s bodies. People should reduce the amount of fish they eat to decrease the chances of suffering from hearing loss. Industrial mercury exposure can be reduced by lowering using raw materials that release mercury. Industries should also use substitution by using non-mercury alternatives (Castellanos and Fuente, 2016). This motive can be one of the primary preventive measures for reducing the entire flow of mercury in the economy and environment. Lead poisoning can be reduced by maintaining adequate calcium and zinc levels in the body (Castellanos and Fuente, 2016). High calcium reduces the chances of lead absorption and raises vitamin c consumption to trigger lead elimination. To control the chances of increased lead effects among the employees, testing workplace air can be beneficial in preventing the lead level. It is essential to inform employees that the job involves exposure to lead hence offered appropriate education to protect themselves against exposing themselves to lead. Establish controls for lead dust and fumes in the workplace, and Protective clothing might be used to prevent workers from coming into contact with lead.

Aminoglycosides are strong antibiotics used worldwide despite their effects on sensorineural hearing loss. The antibiotics cause ototoxicity even if the aminoglycosides concentration is within the required therapeutic range (O'Sullivan et al., 2017). Analysis has indicated that the cumulative duration of using the antibiotics produces ototoxicity effects. To control the effects caused by the antibiotics, reducing their intake can be the best method used by impairing the intake or enhancing their release from the body. Application of the antibiotics once per day can also be used to reduce the effects caused by the antibiotics. Another protective measure that can be used is the co-administration of polyaspartic acid. These steps can play a significant role in reducing the chances of an individual developing a hearing problem. In addition, antibiotics should be avoided for individuals who have myasthenia gravis because they can cause prolonged neuromuscular blockade.

To minimize exposure to trichloroethylene, it is essential for individuals working in areas prone to the chemical to wear protective equipment to reduce contact with the chemical. People should avoid drinking water contaminated with the chemical and avoid areas where the soil is contaminated with the chemical. To prevent aminoglycosides ototoxicity, it comprises careful monitoring of serum drug level and hearing evaluation before, during, and after therapy to determine the chemical level in the body so that necessary steps can be used to prevent adverse effects caused by the chemical in the body.

Exposure to heavy metals destroys auditory components of the inner ear, causing acoustic harm. Heavy metals effects control can be done by applying gastric lavage, ascorbic acid intake, and divalent cation therapy. Hearing loss induced by heavy metals can be extreme due to its adverse destruction of the auditory system (Behar, 2021). Chelating agents might be used in the acute toxicity phase of the effects of the heavy metals. There should be protective legislation against the use of heavy metals in households like alloys in cooking. Industries that use heavy metals as raw materials should put up protective measures that ensure employees are exposed to heavy metals at minimal rates by providing protective equipment.

Controlling the effects of hearing loss by firearms and explosive noise in the workplace involves many strategies. To reduce workplace noise, it is essential to decrease vibration as much as possible. Noise reduction can also be made by placing a barrier between employees' noise source and workstation and the noise source's isolation in an insulated room (Behar, 2021). The strategy can play a significant role in reducing noise in an occupational setting. People can prevent hearing loss caused by firearm noise by using appropriate hearing protective devices, for example, earplugs or earmuffs. Regulation should be put in place to control the number of rounds of shooting allowed to prevent a lot of noise caused by shooting continuously. In addition, smaller caliber firearms should be advocated for target shooting and hunting. Gun shootings should be regulated to prevent increasing noise levels in the society where guns are owned without restrictions; also, restriction of shooting in groups should be imposed. Noise control can play a significant part in minimizing hearing problems in the workplace and while using firearms.

Auditory harm can be caused by noise pollutants, which can be controlled. To ensure individual hearing health is maintained, proper strategies should be put in place to ensure no chemical solvents or compound exposure that can affect unique hearing capabilities. Employees who work in industries that use harmful chemicals and solvents should always wear protective equipment and minimize contact with the chemicals. It is essential to put defensive strategies and appropriate methods for early detection of ototoxic effects. Early detection of ototoxic products can enable an individual to seek medical attention or prevent further exposure to harmful chemicals. There is no sure way to reverse the effects of ototoxic, but the best way is to avoid any possible exposure to the chemicals. Therefore, everyone should be careful to prevent chances of experiencing hearing loss due to ototoxic effects.

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