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Effects of Occupational Noise Exposure on Arterial Blood Pressure, Pulse Rate, and Hearing Threshold Levels in Workers in Selected Industrial Plants in Nablus City

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Dedication

This thesis is dedicated to my mother and to the memory of my father, as well as, to my wife, my brothers and sisters…With love and respect.

Special dedication is to be presented to the souls of all martyrs who sacrificed themselves for the sake of our beloved homeland, Palestine.

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TABLE OF CONTENTS

CHAPTER THREE: RESULTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance.
ANSI	American National Standards Institute.
ASHA	American Speech-Language-Hearing Association.
d	Dyne.
dB	Decibel (s) (unit of sound level using a logarithmic scale).
dB(A)	A-Weighted Decibel (s); also written as dBA.
DBP	Diastolic Blood Pressure.
e.g.	For Example.
EPA	U.S. Environmental Protection Agency.
F1	Vegetable Oils Factories [Food Production].
F2	Arabic Paints Company [Chemical Production].
F3	Al- Carton Factory [Paper Production].
F4	Al-Aqad Company [Sewing Machines].
F5	Al-Andalus Factories [Plastic Production].
F6	Al-Nasir Factory [Paper Production].
F7	Al-Arz Factory [food production].
F8	Cans Factory [Metal Production].
Fig.	Figure (s).
H.I	Hearing Impairment.
HIL	Hearing Impairment Level.
H.R	Heart Rate.
HLPP	Hearing Loss Prevention Program.
hr	Hour (s).

HTL	Hearing Threshold Level.
Hz	Hertz.
i.e.	That is.
IHD	Ischemic Heart Disease.
ISO	International Standards Organization.
kHz	Kilohertz.
km	Kilometer.
L	The Steady State Noise Level in dB(A).
L_A	A-Weighted Sound Level.
$L_{Aeq, 8hr}$	Equivalent Continuous Sound Level for 8 hr; also written as $L_{eq, (8)}$.
$L_{Aeq, 24}$	Equivalent Continuous Sound Level for 24 hr; also written as $L_{eq, (24)}$.
$L_{Aeq, T}$	Equivalent A-Weighted Sound Level Over a Period T.
L_{Amax}	Maximum Sound Level.
L_{dn}	Day-Night Sound Level.
L_{NP}	Noise Pollution Level; also written as NPL.
m	Meter (s).
μ	Micro.
min	Minute (s).
N	Newton (s).
n	Number (s).
NIHL	Noise-Induced Hearing Loss.
NIOSH	National Institute for Occupational Safety and Health.

OSHA	Occupational Safety and Health Administration.
P.R	Pulse Rate.
Pa	Pascal (unit of pressure).
PCBS	Palestinian Central Bureau of Statistics.
PEL	Permissible Exposure Limit.
PRESS	Program to Reduce Exposure by Surveillance System.
R	Person Correlation Coefficient.
REL	Recommended Exposure Level.
RMS	Root Mean Square.
s	Second (s).
SBP	Systolic Blood Pressure.
SEL	Sound Exposure Level.
SIL	Speech Interference Level.
SLM	Sound Level Meter.
SPL	Sound pressure Level(s).
SWL	Sound Power Level.
TWA	Time-Weighted Average.
yr.	Year (s).

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ABSTRACT

Two hundred and eight (208) male workers from eight industrial plants in Nablus city were monitored for noise exposure during a normal work shift. All subjects had no history of heart or hearing disorders. The mean age of subjects is 34.85 ± 2.43 yr. [mean ± standard deviation (SD)], and the mean duration of employment in the current job is 8.55 ± 2.71 yr. [mean ± SD]. The mean working hours in all study locations is 11.25 ± 1.04 hr/day [mean ± SD]; 10 hr/day in 37.5 % of studied industrial plants and 12 hr/day in 62.5 % of them. The working hours in all studied industrial plants are more than 8 hr/day as most international regulations recommended.

Resulting equivalent continuous sound pressure levels (SPL) in dB(A) [L_{Aeq} - values] in all studied plants ranged from 77.4 to 92.4 dB(A), with an arithmetic mean value of 84.43 ± 4.34 dB(A) [mean ± SD]. The noise mapping performed at most of these plants showed that for most part of working hours, the noise levels exceeded the permissible levels set by the international standards.

Results of the audiometric examinations showed that the hearing threshold levels (HTL) were significantly higher than permissible international standards at most frequencies. Strong positive correlation (Pearson correlation coefficient) [$p < 0.05$ and $p < 0.01$] was found between occupational noise pollution levels (NPL) and hearing threshold levels at most frequencies. Significant interactions were found between percentage of several degrees of hearing impairment [according to ANSI, OSHA, NIOSH & ASHA, and EPA's definition] in both ears of subjects and occupational noise levels, age, and duration of employment. There are significant hearing threshold shifts in right and left ears of subjects in different locations, shortly before exposure to occupational noise and during exposure of at least 4 hours from the beginning of morning shift.

In this study, pulse rate (P.R), systolic and diastolic blood pressure (SBP & DBP) correlated positively ($p < 0.05$) with the occupational noise levels in most studied industrial plants. In addition, this work also showed that there are significant shifts in mean values of these variables shortly before exposure to occupational noise (pre-exposure) and during-exposure of at least 4 hours after work onset. Significant interactions were found between mean values of pulse rate, systolic and diastolic blood pressure, length of employment, and age of subjects.

Based on the results of demographic and health status questionnaire. There is an association between exposure to high level of occupational noise pollution in long-term duration and feeling of nervous tension, low concentration, nausea, dizziness, migraine headache, hearing impairment, and muscle contraction, which are related to mental and physiological health effects. There are considerable differences between the frequency and percentage of feeling of mental [nervous tension, sleep disturbance] and physiological [hearing impairment] disease cases before and after receiving the current job. There is a relationship between work accidents and exposure to high levels of occupational noise as a source of annoyance, stress, and dissatisfaction.

Many things can be done to mitigate occupational noise emissions and their impacts on human health in workplaces. Some of these are: shifting noisy sources away from residential areas, suppression of the occupational noise at the sources by shielding the source of noise generation, limiting the exposure time of the workers, following safety and health regulations, consider the noise consequences when designing factories' building, and other actions which are recommended in chapter four of this study.

CHAPTER ONE

Introduction

1.1 Description of noise pollution

The aural sensation that we call sound is caused by the interaction between small pressure variations in the air around our hearing mechanism and us. The small pressure variations are associated with the oscillations of the particles of which air is composed. These oscillations will originate with the disturbance of air-particles adjacent to any vibrating surface in air, which we call a sound source and are transmitted subsequently through the air from particle to particle as a consequence of the forces that exist between the particles of the air. The particles are not carried along with the disturbance, they simply oscillate to and fro about their equilibrium or average undisturbed positions as the disturbance passes (World Health Organization [WHO], 1995).

Sound is caused by vibrations in the air - or some other medium - that reach the ears and stimulate a sensation of hearing, it is called noise when it becomes loud or disagreeable, particularly when it results in physiological or psychological harm (Raven *et al.*, 1993).

Sound is energy in the form of an air pressure wave. Any vibrating body, whether it be a violin string, a loud speaker, or a machine, sets up in the surrounding air a series of pressure changes in the form of waves of alternating compression of the gas molecules. These variations may be carried through a medium like air in all directions over a distance to induce vibration of a surface such as a wall panel or parts of the human ear. When these changing pressures strike the ear, they may be heard as sound, depending upon the amplitude of the wave (sound pressure), and how rapidly the source is vibrating (frequency). Physical pictures of these phenomena are the waves propagated out from the point at which a pebble is dropped into a pond. Sound waves may be reflected, refracted (bent around corners) and absorbed, such as by acoustic material. The quantity usually determined when measuring noise is sound pressure. An understanding of pressure waves, frequency, and the decibel unit is necessary in order to evaluate noise (Purdom, 1980).

1.1.1 Decibel

The range of sound pressure generally encountered is extremely large. For example, the weakest sound pressure heard by a young person with good hearing, at a frequency of 1,000 cycles per second, is about 0.00002 newtons per square meter (2×10^{-5} N/m^2). On the other hand, the highest sound pressure perceived without pain is about 100 newtons per square meter. Therefore, the scale of sound pressures normally encountered covers a range of 1:1,000,000. This range of more than a million cannot be scaled linearly with a practical instrument. In order to cover this extreme range of sound pressures with a reasonable number of scale divisions and to provide a means to obtain the required measurement accuracy at extreme pressure levels, a logarithmic scale, the decibel (dB) is used. In addition, the human ear responds to change in sound pressure logarithmically, rather than in an absolute way. Therefore, it is more convenient to use a logarithmic scale of sound pressure measured in decibels. By definition, the decibel is a dimensionless unit related to the logarithm of the ratio of a measured pressure to a reference pressure. The decibel (dB) is commonly used to describe levels of acoustic energy, power, and pressure, as well as hearing thresholds (Purdom, 1980; WHO, 1999).

1.1.2 Sound pressure level

Most sound-measuring instruments are calibrated to provide a reading of root-mean-square (RMS) sound pressures on a logarithmic scale. The reading taken from the instrument is called a sound pressure level (SPL). The term "level" is used because the measured pressure is at a level above a given pressure reference. Sound pressures are expressed in newtons per square meter (N/m^2), dynes per square centimeter ($dyne/cm^2$) or microbars (μbar) ($1\ N/m^2 = 10\ dyne/cm^2 = 10$ μbars). One microbar is approximately one millionth of normal atmospheric pressure (Purdom, 1980).

For sound measurements in air, 0.00002 N/m^2 usually is the reference sound pressure. This reference is an arbitrary pressure chosen many years ago because it was thought to approximate the normal threshold of human hearing at 1,000 Hz. The sound pressure level is defined mathematically as:

$$SPL = 20 \log_{10} (P/P_o)\ dB$$

where (P) is the measured sound pressure, and (P_o) is the reference pressure, (SPL) is expressed as decibel (dB) referenced to a specified pressure level. For example, in air, the notation for (SPL) is commonly abbreviated as dB re 0.00002 N/m^2 (Dara, 1997; WHO, 1995).

Appendix (A.1) shows the relationship between sound pressure in N/m^2 and sound pressure level in dB re 0.00002 N/m^2 and illustrates the advantage of using the dB scale, rather than the wide range of direct pressure measurements. The scale of sound pressure levels of 1:1,000,000 is reduced to 0-120 dB (Purdom, 1980).

The factor of 20 appears because the energy in the sound wave or the sound intensity is proportional to the square of the sound pressure. It follows from the properties of logarithms is that it is possible to have zero SPL even in the presence of sound. Consider the SPL corresponding to a sound pressure of 2×10^{-5} Pa. This happens to be the same as the reference pressure, and the corresponding SPL is = 20 log 1 = 0 dB. Consequently, the range of sound pressure levels with which we are concerned in the study of noise and noise control, is from 0 dB to some what less than 140 dB. This is less daunting than the range 2 x 10^{-5} to 20 Pa, and as mentioned earlier, is one of the reasons for employing the logarithmic scale (WHO, 1995).

1.1.3 Frequency

The frequency of a sound source is the number of vibrations per second. The unit of frequency is the cycle per second or hertz (Hz). A low-pitched note has a low frequency and a high-pitched note has a relatively high frequency depending upon the age of the listener. Humans can detect sounds between 20 Hz to approximately 20,000 Hz. Exposures to frequency ranges that are considered infrasonic (below 20 Hz), upper sonic (10 to 20 kHz), and ultrasonic (above 20 kHz) (Dara, 1997; Purdom, 1980; WHO, 1995).

1.1.4 Combining decibels - multiple source

Often sound comes from more than one source or at different frequencies and hence, it is necessary to calculate the total or combined sound pressure level. Presented in Appendix (A.2) is a chart, which can be used to combine or add logarithmically two or more decibel levels. For example: The noise level of a small sewing machine is 75 dB, the level of the larger machine is 81 dB, so the difference in the two levels is 6 dB. Therefore, according to the chart, 1 dB is to be added to the higher of the two, resulting in 82 dB for the combined level (Purdom, 1980).

Noise associated with our present lifestyle is a persistent pollutant continuously occurring on a 24-hour, 360° basis. Environmental noise interferes with every phase of human activity as well as impacting all categories of land use (Purdom, 1980).

Noise pollution is an often forgotten environmental problem that is steadily growing in developing countries, it has been recognized as a serious health hazard. The damage from noise to human beings can range from annoyance to insanity and death (Mato & Mufuruki, 1999).

The problem with noise is not only that it is unwanted, but also that it negatively affects human health and well being. Problem related to noise including hearing loss, high blood pressure, high heart rate, muscle contraction, migraine headaches, nausea, dizziness, gastric ulcers, stress, sleep loss, and general reduction in the quality of life and opportunities for tranquility (Hessel & Sluis-Cremer, 1996; Morioka *et al.*, 1993; Resnick, 1998; Sharma *et al.*, 1998).

Noise pollution, adverse effects of noise in our living and working environment. It may be annoying, interferes with speech communication, leisure, or relaxation, and at very high levels which may occur at work or during noisy leisure activities, results in hearing loss by causing damage to the hear-cells in the cochlea in the inner ear, rather than leading to significant adverse physiological responses. However, noise is more often a major problem in terms of quality of human life in specific localities (Purdom, 1980; Raven *et al.*, 1993).

Noise is becoming an increasing problem due to changes in density, urbanization, power generation, and mobility. The generators of noise are numerous, with occupational or industrial noise representing the main problem, followed by operator or passenger exposure to noise. However these sources, in addition to household appliances, are occupationally related noise sources and consequently are not generally classified as community noises. Transportation constitutes the lead source of community noise with surface or vehicular transportation ranking first and aircraft generally ranking second. Many other sources impact the community, including rail vehicles, construction equipment, amplified music, and animals (Purdom, 1980; WHO, 1999).

1.2 Measurements of noise pollution

It is important to measure noise to determine how potentially damaging to hearing, health and well being the noise is. It is also of value to measure and analyze noise to learn its origin and achieve its control. Among the properties of the noise measured are: sound pressure level

(SPL), sound intensity level or sound power level (SWL), time dependence-pulsed or continuous wave, and frequently spectrum (Stumpf, 1980).

Sounds may be characterized in terms of their strength (amplitude) or bandwidth (frequency expressed in cycles per second, or Hertz [Hz]). The most widely used measure of amplitude, measured by a sound level meter (SLM), is decibels (dB). Typical conversational speech is between 65 and 70 dB (WHO, 1999).

The intensity (loudness) of sound is measured relative to a reference sound that is so low, it is almost inaudible to the human ear. Relative loudness is expressed numerically using the decibel (dB) scale or a modified decibel scale called the decibel – A (dB(A)) scale, which takes into account high-pitched sounds to which the human ear is more sensitive (Table 1.1) (Raven *et al.*, 1993).

The effects of sound on a person depend on three physical characteristics of sound: amplitude, frequency, and duration. Sound pressure level (SPL); expressed in decibels, is a measure of the amplitude of the pressure change that produces sound. This amplitude is perceived by the listener as loudness. In sound-measuring instruments, weighting networks are used to modify the sound pressure level (SPL). Exposure limits are commonly measured in dB(A). When used without a weighted network suffix, the expression should be dB SPL (National Institute for Occupational Safety and Health [NIOSH], 1998).

Physically, there is no distinction between sound and noise. Sound is a sensory perception and the complex pattern of sound waves is labeled noise (WHO, 1999).

Most environmental noises can be approximately described by several simple measures. All measures consider the frequency content of the sounds, the overall sound pressure levels (SPL) and the variation of these levels with time. Sound pressure is a basic measure of the vibrations of air that make up sound. Because the range of sound pressures that human listeners can detect is very wide, these levels are measured on a logarithmic scale with units of decibels. Consequently, sound pressure levels (SPL) can not be added or averaged arithmetically. Also, the sound levels of most noises vary with time, and when sound pressure levels (SPL) are calculated, the instantaneous pressure fluctuations must be integrated over some time interval (U.S Environmental protection Agency [EPA], 1974; WHO, 1999).

Table 1.1. The decibel -A scale [dB(A)].

dB(A)	Example	Perception/General Effects
0		Hearing threshold
10	Rusting leaves, breathing	Very quiet
20	Whisper	Very quiet
30	Quiet rural area (night)	Very quiet – quiet
40	Library	Quiet
50	Quiet neighborhood	Quiet – moderately loud
60	Average office conversation	Moderately loud
70	Vacuum cleaner, television	Moderately loud
80	Washing machine, typical factory	Very loud, intrusive
90	Motorcycle at 8 meters	Very loud, impaired hearing with prolonged exposure
100	Dishwasher (very close), jet fly over at 300 meters	Very loud – Uncomfortably loud
110	Rock band, boom box held close to ear	Uncomfortably loud
120	Chain saw	Uncomfortably loud – painfully loud
130	Riveter	Painfully loud
140	Deck of aircraft carrier	Painfully loud
150	Jet at takeoff	Painfully loud – ruptured eardrum

Note: From *Environment* (p. 440), by P.H. Raven, L.R. Berg, & G. B. Johnson (1993). New York: Saunders College Publishing.

Most environmental sounds are made up of a complex mix of many different frequencies, each frequency refers to the number of vibrations per second of the air in which the sound is propagating and it is measured in Hertz (Hz). The audible frequency range is normally considered to be 20-20,000 Hz for younger listeners with unimpaired hearing. However, our hearing systems are not equally sensitive to all sound frequencies, and to compensate for this various types of filters or frequency weighting have been used to determine the relative strengths of frequency components making up a particular environmental noise. The A-weighting is most commonly used and weights lower frequency as less important than mid- and higher-frequencies. It is intended to approximate the frequency response of our hearing system (WHO, 1999).

The effect of a combination of noise events is related to the combined sound energy of those events (the equal energy principal). The sum of the total energy over some time period gives a level equivalent to the average sound energy over that period. Thus, ($L_{Aeq, T}$) is the energy equivalent level of the A-weighted sound over a period T. ($L_{Aeq, T}$) should be used to measure continuing sounds, such as road traffic noise or types of more - or - less continuous industrial noises. However, when there are distinct events to the noise, as with aircraft or railway noise, measures of individual events such as the maximum noise level ($L_{A\ max}$), or the weighted sound exposure level (SEL), should also be obtained in addition to ($L_{Aeq, T}$).

Time-varying environmental sound levels have also been described in terms of percentile levels (NIOSH, 1998; WHO, 1999).

1.3 Sources of noise pollution

There are various sources of noise that can affect the community, namely, noise from industry, transportation, and from residential and leisure areas. It should be noted that equal values of ($L_{Aeq,\,T}$) for different sources do not always imply the same expected effect (WHO, 1999).

1.3.1 Industrial or occupational noise

Mechanized industry creates serious noise problems. It is responsible for intense noise indoors as well as outdoors. This noise is due to machinery of all kinds and often increased with the power of the machines. Sounds generation mechanisms of machinery are reasonably well understood. The noise may contain predominantly low or high frequencies, tonal components, be impulsive or have unpleasant and disruptive temporal sound patterns. Rotating and reciprocating machines generate sound that includes tonal components, and air-moving equipment tends also to generate noise with a wide frequency range (WHO, 1999).

In 1981, occupational safety and health administration (OSHA) estimated that 7.9 million U.S. workers in the manufacturing sector were occupationally exposed to daily noise levels at or above 80 dB(A). In the same year, the U.S. environmental protection agency (EPA) estimated that more than 9 million U.S. workers were occupationally exposed to daily noise levels above 85 dB(A) (NIOSH, 1998).

1.3.2 Transportation noise

Transportation noise is the main source of environmental noise pollution, including road traffic, rail traffic and air traffic. As a general rule, larger and heavier vehicles emit more noise than smaller and lighter vehicles.

The noise of road vehicles is mainly generated from the engine and from frictional contact between the vehicles and the ground and air. In general, road contact noise exceeds engine noise at speeds higher than 60 km/hr. The sound pressure level from traffic and be predicted from the traffic flow rate, the speed of the vehicles, the proportion of heavy vehicles, and the nature of the road surface. Special problems can arise in areas where the traffic movements involve a change in engine speed and power, such as at traffic lights, hills, and intersecting roads, or where topography, meteorological conditions and low background levels are unfavorable (for example, mountain areas) (WHO, 1999).

1.3.3 Construction and building services noise

Building construction and excavation work can cause considerable noise emissions. A variety of sounds come from cranes, cement mixers, welding hammering, boring and other work processes. Construction equipment is often poorly silenced and maintained and building operations are sometimes carried out without considering the environmental noise consequences. Street services such as garbage disposal and street cleaning can also cause considerable disturbance if carried out at sensitive times of day. Ventilation and air conditioning plants and ducts, heat pumps, plumbing systems, and lifts (elevators), for example, can compromise the internal acoustical environment and upset nearby residents (WHO, 1999).

1.3.4 Domestic and leisure activities noise

In residential areas, noise may stem from mechanical devices (for example, heat pumps, ventilation systems and traffic), as well as voices, music and other kinds of sounds generated by neighbors (for example, lawn movers, vacuum cleaners and other household equipment, music reproduction and noisy parties). Aberrant social behavior is a well-recognized noise problem in multifamily dwellings, as well as at sites for entertainment (such as sports and music events). Due to predominantly low-frequency components, noise from ventilation systems in residential buildings may also cause considerable concern even at low and moderate sound pressure levels (SPL) (WHO, 1999).

The use of powered machines in leisure activities is increasing. For example, motor racing, off-road vehicles, motorboats, water skiing, snowmobiles etc., and these contribute significantly to loud noises in previously quiet areas (WHO, 1999).

1.4 Adverse health effects of noise pollution

According to the International Program on Chemicals Safety (1994), an adverse effect of noise is defined as a change in the morphology and physiology of an organism, that results in impairment of functional capacity, or an impairment of capacity to compensate for additional stress, or increases the susceptibility of an organism to the harmful effects of other environmental influences. This definition includes any temporary or long-term lowering of the physical, psychological or social functioning of humans or human organs (WHO, 1999).

1.4.1 Noise - induced hearing loss (NIHL)

Noise-induced hearing loss (NIHL) is caused by exposure to high sound levels or duration that damage the hair cells of the cochlea. Initially, the noise exposure may cause a temporary threshold shift, that is a decrease in hearing sensitivity that typically returns to its former level within a few minutes to a few hours. Repeated exposures lead to a permanent threshold shift, which is an irreversible sensorineural hearing loss (NIOSH, 1998).

There are two categories of hearing injury: acoustic trauma and noise-induced hearing loss (NIHL). Exposure to an intense, short-duration noise, such as a gunshot or explosion, which may result in immediate, severe and permanent hearing loss, is classified as acoustic trauma. Acoustic trauma can damage virtually all of the structures of the inner ear, particularly the organ of corti, which may be torn apart. Moderate- intensity exposures such as industrial noise initially cause temporary hearing loss, or temporary threshold shift (NIOSH, 1998).

Prolonged exposure to noise damages hearing. The part of the ear that perceives sound is cochlea, a spiral tube that resembles a snail's shell (see Appendix A.3). Inside the cochlea are approximately 24,000 hair cells that detect differences in pressure caused by sound waves. When the hair-like projections of the hair cells move back and forth in response to sound, the auditory nerve sends a message to the brain. Loud, high-pitched noise injures the hair cells in the cochlea. Because the body does not replace injured hair cells, prolonged exposure to loud noise results in permanent hearing impairment (Raven *et al.*, 1993).

The excessive exposure to noise results in temporary and/or permanent changes in hearing ability in both human and animal subjects.

The noise - induced hearing loss (NIHL) in workers was previously known as industrial deafness and it is still an important problem in occupational health. The degree of noise-induced hearing loss (NIHL) depends on both the characteristics of noise and the individual sensitivity to noise. Exposure to intensive noise changes the structure and function of the basilar membrane, sensory hair cells, the tectorial membrane and tip links, and the cochlear blood flow (Morioka *et al.*, 1997).

Hearing impairment is typically defined as an increase in the threshold of hearing, which is assessed by threshold audiometry. Hearing handicap is the disadvantage imposed by hearing impairment sufficient to affect one's personal efficiency in the activities of daily living. It is usually expressed in terms of understanding conventional speech in common levels of background noise. Worldwide, noise-induced hearing impairment is the most prevalent irreversible occupational hazard. In developing countries, not only occupational noise, but also environmental noise is an increasing risk factor for hearing impairment (Reilly *et al.*, 1998; Resnick, 1998; WHO, 1999; Wu *et al.*, 1998).

In 1995, at world Health Assembly, it was estimated that there are 120 million persons with disabling hearing difficulties worldwide. It has been shown that men and women are equally at risk of noise-induced hearing impairment (WHO, 1999).

Noise has long been recognized as one of the most prevalent workplace hazards. It was identified by NIOSH as one of the 10 leading occupational problems in its consensus conference (NIOSH, 1988). According to the problem of OSHA's hearing conservation amendment (OSHA, 1981), more than 5 million workers are exposed to potentially hazardous levels of noise in manufacturing and utilities. Hazardous levels of noise are defined here as time-weighted average levels of 85 dB(A) and above, although it is well known that some more susceptible workers will incur hearing losses at levels below 85 dB(A). An additional 300,000 agricultural workers, 500,000 construction workers, and approximately 150,000 workers in oil and gas drilling and servicing are exposed to these noise levels (Suter, 1990).

According to OSHA's (1981) estimates, at least one million workers in manufacturing and utilities had sustained occupational hearing impairments greater than 25 dB at the averaged audiometric frequencies of 1000, 2000, and 3000Hz, which is OSHA's definition of hearing handicap.

1.4.2 Cardiovascular and physiological effects

Epidemiological and laboratory studies involving workers exposed to occupational noise, and general populations (including children) living in noisy areas around airports, industries and noisy streets, indicate that noise may have both temporary and permanent impacts on physiological functions in humans. It has been postulated that noise acts as an environmental stressor. Acute noise exposures activate the autonomic and hormonal systems, leading to temporary changes such as increased blood pressure, increased heart rate and vasoconstriction. After prolonged exposure, susceptible individuals in the general population may develop permanent effects, such as hypertension and ischemic heart disease (IHD) associated with exposures to high levels of sound pressure. The magnitude and duration of the effects are determined in part by individual characteristics, lifestyle behaviors and environmental conditions. Sounds also evoke reflex responses, particularly when they are unfamiliar and have a sudden onset (Green *et al.*, 1991; WHO, 1999).

Laboratory experiments and field quasi-experiments show that if noise exposure is temporary the physiological system usually returns after the exposure terminated-to a normal (pre-exposure) state within a time in the range of the exposure duration. If the exposure is of sufficient intensity and unpredictability, cardiovascular and hormonal responses may appear. Including increases in heart rate and peripheral vascular resistance, changes in blood pressure, blood viscosity and blood lipids, and shifts in electrolyte balance (Mg/Ca) and hormonal levels (epinephrine, norepinephrine and cortisol), most of these effects are of interest because of noise-related coronary heart disease. Laboratory and clinical data suggest that noise may significantly elevate gastrointestinal motility in humans (Babisch *et al.*, 1988).

By far, the greatest number of occupational and community noise studies have focused on the possibility that noise may be a risk factor for cardiovascular disease. Many studies in occupational settings have indicated that workers exposed to high levels of industrial noise for 5-30 years have increased blood pressure and statistically significant increases in risk for hypertension, compared to workers in control areas (WHO, 1999).

1.4.3 Mental health effects

Environmental noise is not believed to be a direct cause of mental illness, but it is assumed that it accelerates and intensifies the development of latent mental disorder. Studies on the adverse effects of environmental noise on mental health cover a variety of symptoms, including anxiety, emotional stress, nervous complaints, nausea, headaches, instability, argumentativeness, sexual impotency, change in mood, increase in social conflicts, as well as general psychiatric disorders such as neurosis, psychosis and hysteria (WHO, 1999).

Job (1996) revealed that in addition to subjectively identifiable reactions to noise, a variety of mental-health effects of noise have been suggested by the research. People living in high noise communities (especially around airports or a long ground transportation corridors) have been identified to differ from those with less noise exposure in terms of mental hospital admission rates, depression, headaches, greater susceptibility to minor accidents, and increased reliance on sedatives and sleeping pills.

Large-scale population studies have suggested association between noise exposure and a variety of mental health indicators, such as single rating of well-being, standard psychological symptom profiles, the intake of psychotropic drugs, and consumption of tranquilizers (Job, 1996; Stansfeld, 1992; WHO, 1999).

1.4.4 Effects of noise on residential behavior and annoyance

Noise annoying is a global phenomenon. A definition of annoying is “a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them”(Job, 1996). However, apart from “annoying”, people may feel a variety of negative emotions when exposed to community noise, and may report anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation, or exhaustion (Job, 1996; Klaboe *et al.*, 2000; Melamed & Ribak, 1997; WHO, 1999).

The degree of annoyance depends upon the intensity and frequency of the noise and its variation with time. High frequency noise and impulsive or intermittent noise are much more annoying and irritating as compared to low frequency and continuous noise. Table 1.2 shows the acceptable noise levels for different outdoor and indoor situations (Dara, 1997).

Noise can produce a number of social and behavioral effects in residents, beside annoyance. The social and behavioral effects are often complex, subtle and indirect. Many of the effects are assumed to be the result of interactions with a number of non-auditory variables. Social and behavioral effects include changes in overt everyday behavior patterns (e.g. closing windows, not using balconies, turning TV and radio to louder levels, writing petitions, complaining to authorities), adverse changes in social behavior (e.g. aggression, unfriendliness, disengagement, non-participation), adverse changes in social indicators (e.g. residential mobility, hospital admissions, drug consumption, accident rates), and changes in mood (e.g. less happy, more depressed) (Job, 1996; WHO, 1999).

Table 1.2. Acceptable noise levels for different outdoor and indoor situations.

Location	Acceptable noise level range, in dB(A)
Outdoor:	
Rural	25-35
Residential (urban)	35-45
Business (urban)	45-50
City	45-55
Industrial area	50-60
Indoor:	
Radio, TV studios, hospitals, & classrooms	25-30
Apartments, hotels & conference rooms	35-40
Private offices & court rooms	40-45
Public offices, stores & banks	45-50

Note: From *A Textbook of Environmental Chemistry and Pollution Control* (p. 144), by S. S., Dara (1997). New Delhi: S. Chand & Company LTD.

1.4.5 Effects of noise on performance

It has been documented in both laboratory subjects and in workers exposed to occupational noise, that noise adversely affects cognitive task performance. In children, too, environmental noise impairs a number of cognitive and motivational parameters (WHO, 1999).

Laboratory and workplace studies showed that noise could act as a distracting stimulus. Also, impulsive noise events (e.g. sonic booms) may produce disruptive effects as a result of startle responses. Among the cognitive effects, reading, attention, problem solving and memory are most strongly affected by noise (WHO, 1999).

1.4. 6 Effects of noise on sleep

An effect of noise which appears compellingly demonstrated by the convergent evidence of subjective reports, direct measures in the field, and laboratory studies, is sleep pattern change and sleep loss. Sleep loss is regularly reported as a source of annoyance, stress and dissatisfaction (Job, 1996).

1.4.7 Interference with communication

In plants where audible warning signals are used, the background noise level must be maintained low enough to enable the warning signal audible. Since the speech frequencies lie between 200 and 700 Hz, the background noise must be restricted to the level that it does not mask the frequencies in this range. For judging the interference effects by the background noise, the arithmetical averages of the noise levels in the three octave bands [600-1200 Hz, 1200-2400 Hz and 2400-4800 Hz] are usually calculated. This average level is called speech interference level (SIL). The SIL values in decibels for rendering different types of communication possible are given in Table 1.3 (Dara, 1997).

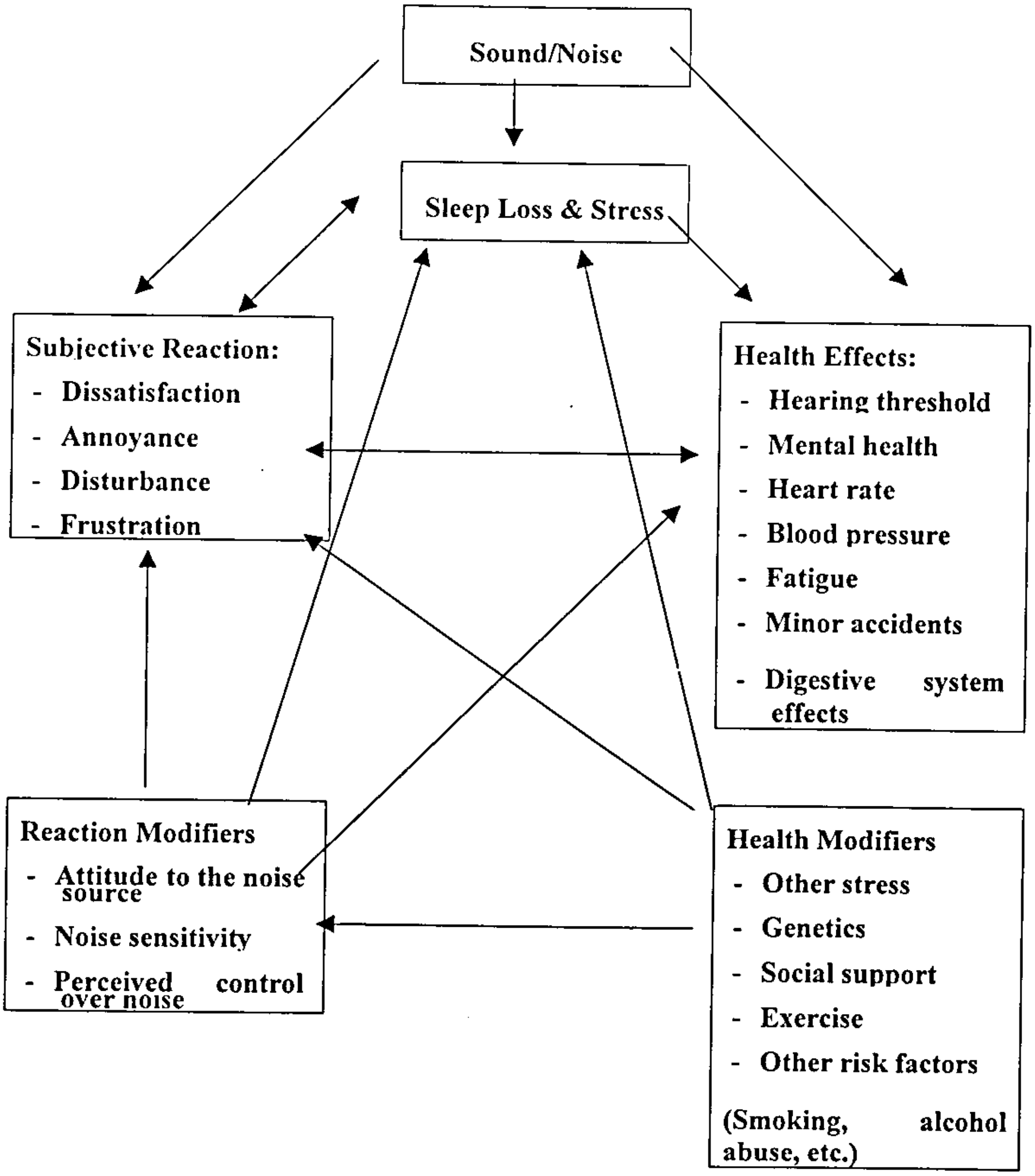
Table 1.3. Speech interference level (SIL) and voice levels required for communication.

Speech interference level (SIL), dB(A)	Voice level and distance within which communication is possible
45	Normal voice at 3m (relaxed conversation)
55	Normal voice at 1m (continuous conversation)
65	Raised voice at 0.6m (intermittent communication)
75	Very loud voice at 0.3m (minimum communication)
85	Shouting at 0.3m (unavoidable communication)

Note: From *A textbook of Environmental Chemistry and Pollution Control* (p.145), by S. S., Dara (1997). New Delhi: S. Chand & Company LTD.

While there are reasonable indicators of a causal connection between noise exposure and health effects, the exact nature of such a causal chain is not known. Fig. 1.1 sets out the likely possibilities for relevant connections (Job, 1996).

Figure 1.1. A model of the causal connections between noise, community reaction, modifiers and health effects.



Note: From the Influence of Subjective Reactions to Noise on Health Effects of the Noise (p. 99), by R. F. S., Job (1996). *Environment International, 22* (1).

Appendix (A.4) presents the WHO guideline values arranged according to specific environments and critical health effects. The guideline values consider all identified adverse health effects for the specific environment. An adverse effect of noise refers to any temporary or long-term impairment of physical, psychological or social functioning that is associated with noise exposure. Specific noise limits have been set for each health effects, using the lowest noise level that produces an adverse health effect. Although the guideline values refer to sound levels impacting the most exposed receiver at different environments, they are applicable to the general population. The time base is given for evenings, but typically the guideline value should be 5-10 dB lower than in daytime. Other time bases are recommended for schools, preschools and playgrounds, depending on activity (WHO, 1999).

1.5 Previous studies

The problem of noise pollution was studied in the region of Arraba in Palestine as an example of the countryside regions, which were expected to be acceptable as a residential area. The equivalent noise level values (L_{eq}) were measured and tabulated for 20 locations spread over the area of the town. The average noise level from the 20 locations was 67.0 dB(A). It was found that the L_{eq} values for 60% of the selected locations were exceeding 65.0 dB(A). This result is obviously higher than adopted international standards. Accordingly, the area of Arraba town was considered as an unacceptable living area (Qamhieh *et al.*, 2000).

Abdel-Raziq (2000) studied the effects of noise pollution on arterial blood pressure, pulse rate and hearing threshold in school children. He found strong positive correlation (Pearson correlation coefficient) between noise pollution level, systolic and diastolic blood pressure, pulse rate, and hearing threshold at different frequencies. The mean systolic and diastolic blood pressure for the two sexes in Abdel-Raziq study correlated positively with the noise pollution level ($R = 0.521$ and 0.440, respectively). Also the hearing threshold levels of different frequencies correlated positively with the noise pollution level ($R = 0.114$ to 0.267; where $p < 0.05$).

Abdel-Ali (2001) studied the noise pollution in factories in Nablus city. The study was concerned in measuring the equivalent noise levels (L_{eq}) in 38 factories in Nablus city, then comparing them with the international standards of occupational noise levels. The obtained mean-value of L_{eq} was 85.5 dB(A), and the L_{eq} values for 40% of the selected factories were higher than the adopted international standards [$\geqslant$85 dB(A)].

In a household environmental survey on exposure to noise in Palestine, it was indicated that 69.4% of households in the West Bank were seldomly exposed to noise, against 62.8% in Gaza Strip. The percentages of households that were sometimes exposed to noise were 18.5% in Gaza Strip and 14.3% in West Bank, while 16.9% of households in the Palestinian territory are exposed to noise very often. The survey also showed that traffic was the most important source of noise in the Palestinian area for 54.2% of households, whereas construction work was the most important source of noise for 44.0% of households in the Gaza Strip and for 24.7% in West Bank (Palestinian Central Bureau of Statistics PCBS, 1998). This qualitative survey was based on a household survey using a special questionnaire only.

The perceived impact of rising traffic noise exposure on residents in five rural Alpine communities in Austria, was assessed in an epidemiological study (1998 adults, aged 25 – 56), using subjective and objective exposure indices. Significant associations were found between noise exposure above 55 dB(A) and annoyance from noise, vibrations, exhaust fumes and soot/dust exposure (Lercher & Kofler, 1996).

A study on the association between industrial noise exposure, noise annoyance, and serum lipid/lipoprotein levels in male (n = 1,455) and female (n = 624) blue – collar workers in Israel. Found that young men (i.e., $\leq$44 yr. of age) exposed to high noise levels ($\geq$ 80 dB(A)) had higher total levels of cholesterol (p = 0.023) and triglycerides (p = 0.001), as well as a higher cholesterol ratio (p = 0.038), than men exposed to low noise levels, even after controlling for confounding variables (Melamed & Ribak, 1997).

A study on noise and hearing ability profiles was determined in a textile factory in Vietnam. Noise mapping done in the weaving section showed that the noise levels exceeded the Vietnamese standard of 90 dB(A) by as much as 9 dB(A) in some areas. Audiometric tests performed on 69 female workers from the weaving section revealed that workers with more than 10 years of noise exposure had the worst hearing threshold levels at 1,000 and 4,000 Hz. Similar findings were observed for workers greater than 35 years old. The 4,000 Hz notch, suggestive of exposure to intense noise, was noted in the audiogram of 26 subjects (Nguyen *et al.*, 1998).

Farahat et al., (1997) found that there was a significant increase in hearing threshold among exposed workers in printing factory in Menoufia in Egypt at frequencies of 1,000 - 8,000 Hz. Within the exposed workers, a significant association was found between hearing threshold and blood lead levels; the hearing threshold rose as the blood lead level increased, especially at 8,000 Hz. As duration of work increased (that is, years of exposure), the exposed workers hearing thresholds increased, reaching a maximum at 8,000 Hz.

To understand the extent of noise-included hearing loss (NIHL) among noise-exposed workers, an ongoing public health surveillance system (Program to Reduce Exposure by Surveillance System or PRESS-NIHL) was established in Taiwan in 1995 to monitor the prevalence of NIHL. A total of 9,535 noise-exposed (>85 dB(A)) workers were recruited into PRESS-NIHL from January to June 1995. Each received a periodic annual audiometric examination at 1 of 73 well-qualified audiometric examination rooms in accredited hospitals. Among these examined 9,463 audiograms were acceptable for evaluation to determine the severity of NIHL at 4 kHz. The mean hearing threshold at 4 kHz was 36.8 dB among male workers and 29.7 dB among female workers. The mean hearing loss at 4 kHz of male workers was higher than that of female workers. Among both man and women, hearing ability was found to decrease with increasing age. A total of 3,216 (34.0%) workers were found to have NIHL, with a hearing threshold higher than 40 dB in either one or both ears. Among these workers 1,886 (19.9%) had mild NIHL (hearing threshold between 40 and 55 dB A) and 1,330 (14.1%) had severe NIHL (hearing threshold above 55 dB A) in either one or both ears (Wu *et al.*, 1998).

Resnick (1998) revealed that noise can cause injury to structures involved in hearing, resulting in permanent impairment or loss of hearing to the point of deafness. Noise-induced hearing loss (NIHL) in the occupational setting is a compensable injury in the United States and many other countries.

An occupational noise exposure study was conducted on a group of 37 communications workers who wear closed-back circumaural headsets in Maryland. These workers underwent reevaluation audiometric testing, and were monitored for noise exposure during a normal work shift. Equivalent continuous sound level range from 79.9 to 103.7 dB(A), with a mean value of 87.0 dB(A). The maximum peak values ranged from 119.2 to 148.8 dB(A), with a mean of 140.8 dB(A). Equivalent continuous sound levels and peak sound levels were compared with the gender, age, work, experience and smoking status of each subject. Comparison of noise exposure level with demographic variables, as well as comparisons within each subject's L average data failed to show statistically significant differences ($p \leq 0.05$) (Chiusano *et al.*, 1995).

A study on a group of Italian patients who were exposed to occupational noise pollution, suggested that the exposition to acoustic defilement during work activity, might be considered as an etiological factor for development and progression of sensorineural hearing impairment, and more extensively for the occurrence of cardiovascular complication (Solerte *et al.*, 1991). A survey in Sweden showed that 79.5% of all persons between 15 and 20 years applying for jobs had hearing troubles caused by noise exposure (Barrekette, 1974).

According to the survey that was done to compare blood pressure in deaf-mute children and children with normal hearing, it was suggested that noise exposure is associated with higher systolic and diastolic blood pressure (Wu *et al.*, 1998).

Significant associations were found in Germany between noise and potential ischemic heart disease (IHD) risk factors, including systolic blood pressure, oestradiol, total cholesterol, plasma viscosity, antithrombin (increases), cortisol, and platelet count (decreases) (Babisch *et al.*, 1988).

Green et al. (1991) suggested that industrial noise exposure is associated with higher ambulatory blood pressure and heart rates in men under 45 years old, but the effect on blood pressure appears to diminish considerably with age. Another study on the effects of an urban noise pollution on blood pressure and heart rate in preschool children, showed that children attending kindergartens situated in areas with traffic noise > 60 dB(A) had higher mean systolic and diastolic blood pressure and lower mean heart rate than children in quiet areas (Regecova & Kellerova, 1995).

A study on the patients perception of sound levels in a surgical suite in National University Hospital in Singapore, revealed that the L_{eq} during the induction, maintenance, and recovery phases were 70.3 ± 4.1 dB(A) and 71.8 ± 6.1 dB(A), respectively. These sound levels were much higher than international recommendations for hospital acute care areas and exceeded the threshold to produce noise-induced cardiovascular and endocrine effects (Liu & Tan, 2000).

An acoustical environment survey was carried out in six similar air-conditioned landscaped offices in which human speech was considered to be the major source of complaint. Both questionnaire and physical noise measurement were administrated. Physical noise measurement data reveal higher sound energy within the human speech frequency range and high speech intelligibility level in the offices (Tang & Wong, 1998).

Shaikh (1999) showed that occupational noise is one of the major environmental problems in industrial plants. Therefore, in order to limit high level occupational noise, maximum permissible occupational noise exposure limit in the range of 85 - 90 dB(A) L_{eq} for 8 hr / day (40 hr / week) have been allowed by the International Standards Organization (ISO) and other developed countries. But in developing countries, most of the industrial plants work for 8 hr / day and 6 days / week, i.e. 48 hr / week. For such plants there is a need to set a different limit; a limit of 88 dB(A) L_{eq} for 8 hr / day and 48 hr / week with halving rate of 3 dB(A) was being proposed.

A survey of personal noise exposure has been in progress in Beijing, China, since 1989 and the data on 221 subjects have been collected so far. The ($L_{eq,\ 24}$) values of 86% of subjects are higher than 70 dB and the average noise exposure level ($L_{eq,\ 24}$) is 75.6 dB for residents of Beijing. The classification of the personal noise exposure patterns depends on age, sex, and, especially, occupation. The personal noise exposure pattern varies with time of day, and it depends mainly on the noise levels of personal activities in daily life. The greatest exposure to noise is during work activities (Zheng *et al.*, 1996).

A study on the noise emission levels in coal industry in India, showed that the noise levels in coal washers, coal preparation plants, open cast and underground mining centers were very high when compared to accepted limits for occupational noise exposure. The continuous exposure of the workers to such high noise levels can cause noise induced permanent threshold shift (NIPTS) in their hearing. It was observed that NIPTS in the 3-5 kHz frequency region instead of the speech frequency range was an early indicator to identify high susceptibility workers (Sharma *et al.*, 1998).

A study on the noise pollution associated with the operation of the Dar Es-Salaam International Airport in Tanzania revealed that the operation of airports resulted in environmental impacts associated with high levels of noises and vibrations. These may have severe negative effects to both workers and surrounding residents and their properties (Mato & Mufuruki, 1999).

To assess the degree of noise pollution in relation to the health and safety of the employees and commuters, a study on the levels of noise originating from various locomotives and also from different other sources was undertaken at Kalupur railway station of Gujarat State in India. The sound pressure levels (SPL) were measured on platforms. Noise dose count was monitored on a ticket collector on duty for 8h. The results reflected that the SPLs in the platforms well exceeded the daytime noise exposure limit. Further, the SPLs produced by loudspeakers were high and those by train whistles were intensely high-pitched (Bandyopadhyay *et al.*, 1994).

1.6 Noise management

The fundamental goals of noise management are to develop criteria for deriving safe noise exposure levels, to promote noise assessment and control as part of environmental health programs. These basic goals should guide both international and national policies for noise management (WHO, 1999).

In all cases, noise should be reduced to the lowest level achievable in the particular situation. When there is a reasonable possibility that the public health will be endangered, even though scientific proof may be lacking, action should be taken to protect the public health, without awaiting the full scientific proof. The full costs associated with noise pollution (including monitoring, management, lowering levels, and supervision) should be met by those responsible for the source of noise. Action should be taken where possible to reduce noise at the source (NIOSH, 1998).

Components of a noise management plan include noise level monitoring, noise exposure mapping, exposure modeling, noise approaches (such as: mitigation and precautionary measures), and evaluation of control options. Many of the problems associated with high noise levels can be prevented at low cost, if authorities develop and implement an integrated strategy for the indoor environment, in concern with all social and economic partners. Authorities should establish a national plan for a sustainable noise indoor environment, which applies both to new construction as well as to existing buildings (NIOSH, 1998; WHO, 1999).

The concept of an environmental noise impact analysis is central to the philosophy of managing environmental noise. Such an analysis should be required before implementing any project that would significantly increase the level of environmental noise in community. The analysis should include: a baseline description of the existing environmental noise, the expected level of noise from the new source, an assessment of the adverse health effects, an estimation of the population at risk, the calculation of exposure-response relationships, an assessment of risks and their acceptability, and a cost-benefit analysis (WHO, 1999).

Noise management should (NIOSH, 1998; WHO, 1999):

A. Start monitoring human exposures to noise.

B. Have health control require mitigation of noise emissions. The mitigation procedures should take into consideration:

    - Specific environments such as: schools, playgrounds, homes, and hospitals.

- Environments with multiple noise sources, or which may amplify the effects of noise.
- Sensitive time periods such as: evenings, nights, and holidays.
- Groups at high risk, such as: children and the hearing impaired.

C. Consider the noise consequences when planning transport systems and land-use.

D. Introduce surveillance systems for noise-related adverse health effects.

E. Assess the effectiveness of noise policies in reducing adverse health effects and exposure.

F. Adopt precautionary actions for a sustainable development of the acoustical environments.

1.7 Noise policy and legislation

Noise is both a local and a global problem. Governments in every country have a responsibility to set up policies and legislation for controlling noise emissions. There is a direct relationship between the level of development in a country and the degree of noise pollution impacting its people. As a society develops, it increases its level of urbanization and industrialization, and the extent of its transportation system. Each of these developments brings an increase in noise load. Without appropriate intervention the noise impact on communities will escalate. If governments implement only weak noise policies and regulations, they will not be able to prevent a continuous increase in noise pollution and associated adverse health effects. Failure to enforce strong regulations is ineffective in combating noise as well (NIOSH, 1998).

Policies for noise regulatory standards at the municipal, regional, national and supranational levels are usually determined by the legislatures. The regulatory standards adopted strongly depend on the risk management strategies of the legislatures, and can be influenced by sociopolitical consideration and/or international agreements. Although regulatory standards may be country specific, in general the following issues are taken into consideration (WHO, 1999):

a. Identification of the adverse public health effects that are to be avoided.
b. Identification of the population to be protected.
c. The type of parameters describing noise and the limit applicable to the parameters.
d. Applicable monitoring methodology and its quality assurance.
e. Enforcement procedures to achieve compliance with noise regulatory standards within a defined time frame.
f. Emission control measures and emission regulatory standards.
g. Emission standards (limits for sound pressure levels).
h. Identification of authorities responsible for enforcement.

i. Resource commitment.

Noise regulatory standards can set the reference point for emission control and abatement policies at the national, regional or municipal levels, and can thus strongly influence the implementation of noise control policies. In many countries, exceeding regulatory standards is linked to an obligation to develop abatement action plans at the municipal, regional or national levels (low-noise implementation plans). Such plans have to address all relevant sources of noise pollution (Suter, 1994).

Different organizations and institutions in the last 20 years have formulated regulations and standards of different types of noise pollution. The purpose of these regulations and standards is to assure, so far as possible, safe and healthful working conditions for every working man and woman to preserve our human resources (NIOSH, 1998). These organizations and institution including Occupational Safety and Health Administration [OSHA], U. S. Environmental Protection Agency [EPA], National Institute for Occupational Safety and Health [NIOSH], American National Standard Institute [ANSI], International Standards Organization [ISO], and others (see Appendix A.4 – A.9 for different standards). Each organization has certain specifications to the physical quality to be measured and the techniques for the measurements. For further information.

1.8 Objectives of this study

The world attention has increased to provide environmental statistical data on all environmental sectors. Providing such data will participate in legislation and policy making that will reduce the pressure on the environment. As in the rest of the world, the attention has greatly increased in Palestine to provide such data, after many years of environment negligence and the absence of standards and rules during the period of Israeli occupation.

Many studies on environmental noise have been carried out worldwide with various kinds of sound. There is a lack of such studies in Palestine, because of long-term Israeli occupation to our community and land, which had the most direct effects for the absence of controlling authority on the quality of the Palestinian environment, and the lack of data resources in different environmental aspects. These reasons encouraged the researcher to select this subject to share in establishing the databases of the Palestinian environmental issues.

This study aimed to:

- Measure the occupational noise levels generated by machines at different categories of selected industrial plants.

- Determine the surrounding workers' perceptions on resulting noise.

- Provide reliable data on the effects of occupational noise exposure on human health, by investigating the association between the long-term exposure to high-level of the occupational noise, arterial blood pressure (systolic and diastolic), pulse rate, and hearing threshold levels of selected workers in selected industrial plants in Nablus city.

CHAPTER TWO

Methodology

2.1 Study population

Two hundred and eight (208) male workers (aged 25-45 years, with a minimum of 2 years employment duration in the same industrial plant) in eight industrial plants in Nablus city were selected in this study. All subjects had no history of heart or hearing disorders. The number of selected workers who fit the study conditions were taken according to the criteria presented in Table 2.1.

Table 2.1. Explaining criteria for the selecting study population.

Number of workers who fit the study conditions *	Criteria for selecting the number of study population from each industrial plant
25	All of them.
25-50	75%
50-75	50%
75-100	40%
>100	30%

***Study conditions: {Aged 25-45 yr., at least 2-yr. employment duration in the same industrial plant, no history of heart or hearing disorders}.**

This study was conducted between June and September 2001. Field measurements were carried out in central locations in each industrial plant's building, during the morning shift [at least 4 hours after work onset]. The eight industrial plants were distributed in several locations in Nablus city, representing different sectors: chemical, plastic, food, papers, clothes (sewing machines), and metal factories. These industrial plants were also selected according to the production levels, area, year of establishment, number of machines, and the presence of sufficient number of workers. Some features of selected industrial plants (see Appendix B.1 for more information) are presented in Table 2.2.

Table 2.2. The status of the studied industrial plants.

Categories of factories	Name of factory	Location	No. of workers	No. of selected workers	Working hours
Chemical	Arabic Paints	Commercial + Industrial	19	17	10
Plastic	Al-Andalus	Industrial	16	15	10
Food	Vegetable Oils	Industrial + Commercial	35	13	10
	Al-Arz	Residential + Commercial	65	28	12
Paper	Al-Carton	Industrial	45	30	12
	Al-Nasir	Industrial	106	40	12
Clothes (sewing machine)	Al-Aqad	Industrial	110	49	12
Metal	Cans Factory	Industrial	36	16	12

2.2 Instrumentation for noise measurements

The simplest physical measure of noise would be the determination of its overall sound pressure. However, such a measurement would give no indication of the frequency distribution of the noise nor would it give any information as to the human perception of it. In order to make the measured results of noise more meaningful, sound level meters (SLM) are provided with a set of frequency weighted networks, A, B, and C (Purdom, 1980). The frequency response of the three-weighted networks is shown in (Appendix B.2). The C-weighting network shows only little dependency on frequency over the greater part of the audible frequency range while the A-weighting network has a very pronounced frequency dependency for frequencies below 1,000 Hz. The A-weighting network is the most useful one on the sound level meter since it approximates the response of the human ear to sound levels below 55 dB. It indicates the A-weighted sound level often abbreviated dB(A). Significantly, the pertinent provisions of the Occupational Safety and Health Administration (OSHA) of 1970 use occupational permissible noise exposure limits in terms of dB(A) sound level (Purdom, 1980; WHO, 1995).

2.2.1 Sound pressure level measurements

No single method or process exists for measuring occupational noise. The choice of a particular instrument and approach for measuring and analyzing occupational noise depends on many factors, not the least of which will be the purpose for the measurement and the environment in which the measurement will be made (NIOSH, 1998).

The sound level meter (SLM) is the basic measuring instrument for noise exposures. It consists of a microphone, a frequency selective amplifier, and an indicator (Fig. 2.1). An integrating function may be included to automate the calculation of the time-weighted average (TWA) or the noise dose (NIOSH, 1998).

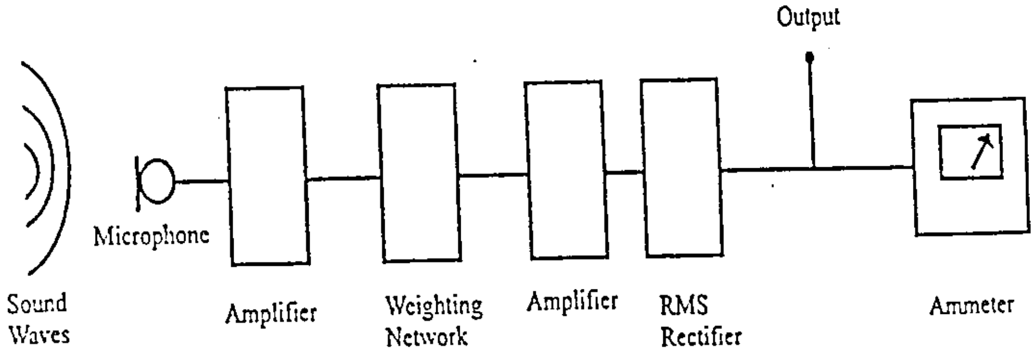


Figure 2.1. Block diagram for sound level meter (SLM).

Sound pressure level (SPL) measurements were carried out by using a logging sound level meter (SLM) (Quest Technologies, U.S.A, model 2900 type 2), in (dB) units with an accuracy of ± 0.5 dB(A) at 25°C and its precision is 0.1 dB(A) (Instruction for Sound Level Meter, 1998). Sound level meter (SLM) instrument was placed in the central locations in the selected industrial plants' buildings, where most of the machines that emit industrial noise are found.

According to international standards of environmental safety, equivalent sound level (L_{eq}) with 3-dB exchange rate was measured in A-weighted decibels [dB(A)]. The obtained results were then evaluated using international standards for acoustics-determination of occupational noise exposure limits, including EPA, ANSI, NIOSH, ISO, and OSHA's standards.

Sound level meter (SLM) responds to sound in approximately the same way as the human ear, which gives objective reproducible measurements of sound level. The sound signal is converted to an identical electrical signal by a high quality microphone. Since the signal is quite small, so it must be amplified. Signal may pass through a weighting network (A, B, or C). Weighting network type A was used in this study. After additional amplification the signal will be high enough to drive the ammeter, and its root mean square (RMS) value has been determined in the RMS detector. The value read on the ammeter is the level in dB(A) (Fig. 2.1) (Diehl, 1973).

2.2.2 Hearing threshold levels measurements

Audiometry, which objectively measures the sensitivity or acuity of hearing (hearing threshold, H.T), was performed twice a day on all selected workers, first just before work onset (pre-exposure), and after at least 4 hours from the beginning of morning shift (during-exposure).

To evaluate the hearing ability of the subjects, pure-tone air conduction audiometric tests were done. Using AM 232 Manual Audiometer (Welch Allyn, 1998), with accuracy of ± 3%, at operating temperature 15°- 40°C, at frequencies, i.e., 125, 250, 500, 750, 1000, 1500, 2000, 3000, 4000, 6000 and 8000 Hz. Test at each frequency was performed separately for each ear. The examinations were conducted in a quiet room with a background noise level less than 50 dB(A). The results of each left and right ear were recorded in an audiogram form (Appendix B.3). Subjects with histories of ear disorders were excluded from this study.

The audiometric tests were evaluated using different definitions of material hearing impairment (also used as hearing impairments) to assess the risk of occupational noise-induced hearing loss (NIHL):

1. Criteria suggested by ANSI (1969) and developed by Katz (1985) (see Appendix B.4).
2. OSHA's definition of hearing handicap also used to determine the degrees of hearing impairments in both ears of the whole study population.

Hearing threshold levels greater than 25 dB at the averaged audiometric frequencies of 1000, 2000, 3000 Hz (the 1-2-3-kHz definition) is estimated by OSHA as hearing handicap (OSHA, 1981).

3. NIOSH and American Speech-Language-Hearing Association's (ASHA) definition also used in this study to define the criteria for maximum acceptable hearing loss. NIOSH and ASHA define material hearing impairment as an average of the hearing threshold levels (HTLs) for both ears that exceeds 25 dB at 1000, 2000, 3000, and 4000 Hz (the 1-2-3-4-kHz definition) (NIOSH, 1998).

4. EPA suggested that human ear, when damaged by noise, is typically affected at the 4,000 Hz frequency first, and, therefore, this frequency can be considered the most noise-sensitive frequency. The averaged frequencies of 500, 1000, and 2000 Hz (the 0.5-1-2-kHz definition) have traditionally been employed in hearing conservation criteria because of their importance to the hearing of speech sounds (EPA, 1974).

2.2.3 Arterial blood pressure and pulse rate measurements

Arterial blood pressure (systolic and diastolic) and pulse rate were measured for each selected worker twice a day, before work onset (pre-exposure), and after at least 4 hours from the beginning of the morning shift (during-exposure). Using Portable Wrist Blood Pressure Monitor

(Omron Healthcare, INC., China, Model HEM-608) with accuracy of ± 3 mmHg or 2% of reading blood pressure, and ± 5% of reading pulse rate. Operating temperature range of +10°C to +40°C (Instruction Manual: Portable Wrist Blood Pressure Monitor, 1996).

The examinations were conducted in a quiet room with a background noise level less than 50 dB(A). To rule out the presence of heart disorders from other cases, the questionnaire was done on all subjects to ask them if they had a history of any cardiovascular and blood pressure diseases. Subjects with histories of heart and circulatory systems disorders were excluded from this study. Results of these tests were related to means of sound pressure levels, duration of employment, and age of the subjects.

Two questionnaires were prepared and employed in this study. The first one (see Appendix B.5) was about conditions of living and working environment (including the production levels, nature of industry, production lines and shifts, location, number of workers and machines, years of the machines under working, and other environmental conditions). The second one (see Appendix B.6) was distributed on all selected workers, contained the study variables (such as age, sex, daily and weekly working hours, duration of employment, health status, and others).

2.3 Statistical analysis

The obtained results were tabulated and statistically analyzed. The statistical package SPSS was used for statistical analysis. Minimum, maximum, mean, and standard deviation (SD) values of each studied variable were expressed. Average values were expressed as group means ± standard deviation (SD). Percentage of most studied variables was also revealed. Analysis of variance (ANOVA) test was used to determine significant differences between occupational noise pollution levels (as an independent variable) and pulse rate, systolic and diastolic blood pressure, and hearing threshold at different frequencies (as dependent variables). Pearson correlation factor (R) was used as a measure of the strength of the correlation between occupational noise pollution levels and the dependent variables. Results of the blood pressure monitor and audiometric examination were related to occupational noise, employment duration, and age of the whole study population. Statistical tests with $P < 0.05$ were considered statistically significant.

CHAPTER THREE

Results

An acoustical environmental survey was carried out in eight selected industrial plants in which machines were considered to be the major dominant occupational noise sources. Seven of these plants (Vegetable Oils, Arabic Paints, Al-Carton, Al-Aqad, Al-Andalus, Al-Nasir, and Cans factory) are located in the eastern part of Nablus city, which is considered by municipality as an industrial zone, and the eighth (Al-Arz) is located near the town center. Appendix (B.1) describes the environmental status of the studied industrial plants.

Two hundred and eight (208) male workers from eight industrial plants in Nablus city were selected as subjects of this study. The mean age of subjects is 34.85 ± 2.43 yr. The mean duration of employment is 8.55 ± 2.71 yr. The studied industrial plants are placed inside residential, commercial, and industrial zones. The design of these plants did not follow any kind of regulations in order to reduce occupational noise pollution.

Questionnaires, physical noise measurements, blood pressure (systolic and diastolic), pulse rate, and audiometric examinations were administrated in this study to investigate the effects of occupational noise exposure on arterial blood pressure, pulse rate, and hearing threshold levels in selected workers in studied industrial plants in Nablus city.

3.1 Occupational noise pollution levels in the studied industrial plants

The measured equivalent sound levels (L_{eq}) in dB(A) in all selected industrial plants are presented in Table 3.1. Number of workers, number of selected workers, and working hours in each selected plant are shown in the Table 3.1.

Table 3.1. Noise pollution levels (NPL) in dB(A) at all studied industrial plants.

Categories of factories	Name of the factory	L_{eq} in dB(A) (Mean value)	No. of workers	No. of selected workers	Working hours per day
Chemical	Arabic Paints Company	81.7	19	17	10
Plastic	Al-Andalus Factory	85	16	15	10
Food	Vegetable Oils Company	77.4	35	13	10
	Al-Arz Factory	86.7	65	28	12
Paper	Al-Carton Factory	83	45	30	12
	Al-Nasir Factory	86	106	40	12
Clothes (sewing machine)	Al-Aqad Company	83.2	110	49	12
Metal	Cans Factory	92.4	36	16	12
Total			432	208	

A total of 432 workers are working in these industrial plants. 208 male subjects were monitored for noise exposure in this study. The ages of them ranged from 25 to 45 yr., with a mean of 34.85 ± 2.43 yr. [mean ± standard deviation (SD)]. The working hours per day ranged from 10 to 12 hr/day, with a mean of 11.25 ± 1.04 hr/day [mean ± SD]. The duration of employment in the current job ranged from 2 to 25 yr., with a mean of 8.55 ± 2.71 yr. [mean ± SD].

The L_{eq} - values of sound pressure levels (SPL) in dB(A) in all studied plants ranged from 77.4 to 92.4 dB(A), with an arithmetic mean of 84.43 ± 4.34 dB(A) [mean ±SD]. 432 workers are working in the studied industrial plants. 51.6% of them (223 out of 432) are daily exposing to occupational noise of 85 dB(A), 40.3% (174 out of 432) are exposing to occupational noise ranged from 80 to <85 dB(A), 8.1% (35 out of 432) are daily exposing to 77.4 dB(A).

Four of the eight studied industrial plants (50%) had occupational noise exposure ≥85 dB(A), 47.5% (99 selected workers) of the whole study population are exposed to these levels. Three of the studied industrial plants (37.5%) had occupational noise ranged from 80 - <85 dB(A), 46.2% (96 selected workers) of whole study population are exposed to these levels. One of the studied industrial plants (12.5%) had occupational noise exposure of 77.4 dB(A), 6.3% of study population (13 selected workers) are exposed to this noise level.

The average working hours in all study locations is 11.25 hr/day; 10 hr/day in 37.5 % of the studied industrial plants and 12 hr/day 62.5 % of them. 21.6% of the subjects (45 out of 208) are working of 10 hr/day, and 78.4% of them (163 out of 208) are working of 12 hr/day. Based on these results, the working hours in all studied industrial plants are more than 8 hr/day as most international regulations recommended.

3.2 Arterial blood pressure (systolic and diastolic) and pulse rate results

Minimum, maximum, mean, and standard deviation of mean values of working hours, duration of employment, age, systolic and diastolic blood pressure (SBP & DBP), and pulse rate (P.R) for all selected workers in each industrial plant are presented in Table 3.2 (a-h) and Table 3.3.

Mean values of pulse rate (P.R), systolic (SBP) and diastolic blood pressure (DBP) correlated positively ($p < 0.05$) with the occupational noise levels in most studied industrial plants. In addition, significant interactions were found between mean values of these variables and length of employment, age of subjects (Tables 3.2 & 3.3).

Table 3.2 (a-h). Minimum, maximum, mean, and standard deviation values of studied variables for selected workers from each industrial plant.

(a) Vegetable Oils Factory (F1)

Variables*	Min.	Max.	Mean	Std. Deviation
Working hours	-	-	10	-
Duration of employment	10	17	11.6	2.63
Age	33	43	36.54	3.1
P. R (b)	57	98	77.77	11.45
P. R (d)	63	97	81.39	9.03
SBP (b)	100	164	122.77	17.25
SBP (d)	111	153	131.62	12.49
DBP (b)	59	97	73.77	12.39
DBP (d)	69	98	81.15	10.33

(b) Arabic Paints Factory (F2)

Variables	Min.	Max.	Mean	Std. Deviation
Working hours	-	-	10	-
Duration of employment	2	13	4.59	2.81
Age	25	45	31	5.67
P. R (b)	56	100	75.94	10.08
P. R (d)	63	91	78.24	7.44
SBP (b)	103	146	122.82	11.1
SBP (d)	112	156	128.29	11.47
DBP (b)	59	93	77.94	9.2
DBP (d)	60	92	79.41	8.11

(c) Al – Carton Factory (F3)

Variables	Min.	Max.	Mean	Std. Deviation
Working hours	-	-	12	-
Duration of employment	2	13	7.96	3.14
Age	17	45	34.57	7.79
P. R (b)	62	101	79.7	10.41
P. R (d)	54	104	84.4	11.85
SBP (b)	108	175	133.77	12.57
SBP (d)	114	168	135	13.58
DBP (b)	62	115	85.3	11.1
DBP (d)	65	104	83.63	10.08

Table 3.2/ Cont.

(d) Al – Aqad Factory (F4)

Variables	Min.	Max.	Mean	Std. Deviation
Working hours	-	-	12	-
Duration of employment	2	17	8.08	3.63
Age	25	45	31.61	7.47
P. R (b)	55	119	79	11.38
P. R (d)	61	150	85.59	14.55
SBP (b)	86	183	129.69	18.11
SBP (d)	33	177	131.41	20.38
DBP (b)	56	118	80.86	13.39
DBP (d)	54	108	81.16	10.16

(e) Al – Andalus Factory (F5)

Variables	Min.	Max.	Mean	Std. Deviation
Working hours	-	-	10	-
Duration of employment	4	12	6.46	1.89
Age	25	45	37.53	5.76
P. R (b)	62	81	72.07	6.03
P. R (d)	65	82	75	4.36
SBP (b)	111	152	121	10.47
SBP (d)	105	140	123.67	10.34
DBP (b)	61	88	70.27	9.16
DBP (d)	62	84	74	8.12

Table 3.2/ Cont.

(f) Al – Nasir Factory (F6)

Variables	Min.	Max.	Mean	Std. Deviation
Working hours	-	-	12	-
Duration of employment	2	21	8.25	4.33
Age	25	45	36.33	6.93
P. R (b)	44	95	75.95	9.44
P. R (d)	61	115	82.33	10.11
SBP (b)	102	151	130.6	11.09
SBP (d)	102	150	132.35	10.67
DBP (b)	68	111	84.25	9.31
DBP (d)	60	102	83.55	9.27

(g) Al –Arz Factory (F7)

Variables	Min.	Max.	Mean	Std. Deviation
Working hours	-	-	12	-
Duration of employment	2	8	5.21	2.09
Age	25	44	34.57	6.55
P. R (b)	53	111	72.96	13.16
P. R (d)	57	97	77.82	10.18
SBP (b)	109	152	127.96	13.02
SBP (d)	108	150	129.85	11.46
DBP (b)	62	101	79.82	11.35
DBP (d)	62	96	81.21	9.30

Table 3.2/ Cont.

(h) Cans Factory (F8)

Variables	Min.	Max.	Mean	Std. Deviation
Working hours	-	-	12	-
Duration of employment	2	25	12.3	5.43
Age	25	45	36.88	36.88
P. R (b)	50	92	72.13	13.45
P. R (d)	53	124	79.44	9.78
SBP (b)	117	192	138.81	22.18
SBP (d)	113	190	142.88	19.56
DBP (b)	68	119	82.25	13.31
DBP (d)	61	100	82.44	9.1

*** Working hours in hr/day. Duration of employment in yr. Age in yr. Pulse rate (P.R) in (beats/min), systolic and diastolic blood pressure (SBP & DBP) in (mmHg) [before (b) exposure (just before work onset) and during (d) exposure (after at least 4 hours from the beginning of morning shift) to occupational noise].**

Table 3.3. Minimum, maximum, mean, and standard deviation values of studied variables for whole study population.

Variables*	Min.	Max.	Mean	Std. Deviation
SPL	77.4	92.4	84.43	4.34
Working hours	10	12	11.25	1.04
Duration of employment	4.58	12.3	8.55	2.71
Age	31	37.5	34.85	2.43
P. R (b)	72	79.7	75.75	3.16
P. R (d)	75	85.5	80.49	3.55
SBP (b)	121	138.8	128.4	6.11
SBP (d)	123	143	131.88	5.68
DBP (b)	70.2	85.3	79.28	5.18
DBP (d)	74	83.6	80.8	3.08

***SPL: Sound pressure levels in dB(A). Working hours in hr/day. Duration of employment in yr. Age in yr. Pulse rate (P.R) in (beats/min), systolic and diastolic blood pressure (DBP) in (mmHg) [before (b) exposure (just before work onset) and during (d) exposure (after at least 4 hours from the beginning of morning shift) to occupational noise].**

3.3 Hearing threshold results

Percentage of degrees of hearing impairment in both ears before (b) and during (d) exposure to occupational noise in whole study population [according to ANSI (1969) and Katz (1985) criteria (Appendix B.4)] are presented in Table 3.4.

Table 3.4. Percentage of degrees of hearing impairment at different sound frequencies in whole study population [according to ANSI (1969) and Katz (1985) criteria].

Degrees of H.I*	Right ear (b) %	Right ear (d) %	Left ear (b) %	Left ear (d) %
1	65.95	58	66.74	56.08
2	28.72	34	27.67	35.4
3	4.5	7	4.32	6.73
4	0.61	0.7	1.14	1.09
5	0.22	0.26	0.13	0.61
6	-	0.04	-	0.09
Total	100	100	100	100

***H.I: Hearing impairment. Degrees of hearing impairment 1: normal (-10 - 26 dB), 2: mild (27 – 40 dB), 3: moderate (41 – 55 dB), 4: moderately severe (56 – 70 dB), 5: severe (71 – 90 dB), 6: profound (91+ dB).**

Percentage of degrees of hearing impairment -according to OSHA, NIOSH & ASHA, EPA's definitions- in each industrial plant is presented in Tables 3.5-3.7.

Table 3.5. Percentage of degrees of hearing impairment in each studied industrial plant [according to OSHA's definition of hearing impairment*].

Industrial plants**	Right ear (b)	Left ear (b)	Right ear (d)	Left ear (d)
	%	%	%	%
F1	46.2 (6/13)	7.7 (1/13)	53.9 (7/13)	30.8 (4/13)
F2	11.8 (2/17)	5.9 (1/17)	35.3 (6/17)	29.4 (5/17)
F3	36.7 (11/30)	40 (12/30)	50 (15/30)	46.7 (14/30)
F4	18.4 (9/49)	24.5 (12/49)	40.8 (20/49)	44.9 (22/49)
F5	46.7 (7/15)	33.3 (5/15)	46.7 (7/15)	33.3 (5/15)
F6	30 (12/40)	37.5 (15/40)	40 (16/40)	40 (16/40)
F7	28.6 (8/28)	17.9 (5/28)	35.7 (10/28)	17.9 (5/28)
F8	31.3 (5/16)	62.5 (10/16)	75 (12/16)	68.8 (11/16)
Total	28.9 (60/208)	29.3 (61/208)	44.7 (93/208)	39.4 (82/208)

*** Average of hearing threshold levels in either one or both ears exceeds 25 dB(A) at 1000, 2000, and 3000 Hz [the 1-2-3-kHz definition].**

****F1: Vegetable Oils, F2: Arabic Paints, F3: Al – Carton, F4: Al – Aqad, F5: Al – Andalus, F6: Al – Nasir, F7: Al – Arz, F8: Cans Factory.**

Table 3.6. Percentage of degrees of hearing impairment in each studied industrial plant [according to NIOSH and ASHA's definition of hearing impairment*].

Industrial plants	Right ear (b)	Left ear (b)	Right ear (d)	Left ear (d)
	%	%	%	%
F1	30.8 (4/13)	46.2 (6/13)	61.5 (8/13)	23.1 (3/13)
F2	11.8 (2/17)	5.9 (1/17)	35.3 (6/17)	23.5 (4/17)
F3	30 (9/30)	40 (12/30)	46.7 (14/30)	46.7 (14/30)
F4	16.3 (8/49)	22.5 (11/49)	49 (24/49)	47 (23/49)
F5	40 (6/15)	46.7 (7/15)	60 (9/15)	53.3 (8/15)
F6	25 (10/40)	30 (12/40)	35 (14/40)	42.5 (17/40)
F7	25 (7/28)	39.3 (11/28)	42.9 (12/28)	46.4 (13/28)
F8	43.8 (7/16)	50 (8/16)	62.5 (10/16)	75 (12/16)
Total	26.7	30.8	46.6	45.2

* Average of the hearing threshold levels for both ears that exceeds 25 dB at 1000, 2000, 3000, and 4000 Hz [the 1-2-3-4-kHz definition].

Table 3.7. Percentage of degrees of hearing impairment in each studied industrial plant [according to EPA's definition of hearing impairment*].

Industrial plants	Right ear (b)	Left ear (b)	Right ear (d)	Left ear (d)
	%	%	%	%
F1	61.5 (8/13)	23.1 (3/13)	76.9 (10/13)	53.9 (7/13)
F2	29.4 (5/17)	17.7 (3/17)	35.3 (6/17)	52.9 (9/17)
F3	20 (6/30)	43.3 (13/30)	36.7 (11/30)	66.7 (20/30)
F4	29.5 (13/49)	32.7 (16/49)	55.1 (27/49)	61.2 (30/49)
F5	66.7 (10/15)	60 (9/15)	73.3 (11/15)	66.7 (10/15)
F6	60 (24/40)	57.5 (23/40)	65 (26/40)	67.5 (27/40)
F7	35.7 (10/28)	14.3 (4/28)	46.4 (13/28)	25 (7/28)
F8	31.3 (5/16)	43.8 (7/16)	56.3 (9/16)	56.3 (9/16)
Total	38.9 (81/208)	37.5 (78/208)	54.3 (113/208)	57.2 (119/208)

*** Average of hearing threshold levels in either one or both ears exceeds 25 dB(A) at 500,1000, and 2000 Hz [the 0.5-1-2-kHz definition].**

Analysis of the audiometric tests conducted showed that 34.05% and 33.26% of the subjects suffer from varying degrees of hearing impairment when their right and left ears, respectively, were examined before exposure [before entering the morning shift] to occupational noise. On the other hand, 42 % and 43.92 % when their right and left ears, respectively, were examined during exposure [after at least 4 hr from entering the same shift] to occupational noise at different frequencies (Table 3.4).

Based on Table 3.5, a total of 28.9% (60 out of 208) of the selected workers were classified to have hearing impairment according to OSHA (1981) [average of hearing levels in either one or both ears exceeds 25 dB(A) at 1000, 2000, and 3000 Hz] in their right ear and 29.3% (61 out of 208) in their left ear, when they were examined before exposure to occupational noise [before entering the morning shift]. On the other hand, 44.7% (93 out of 208) of the selected workers were classified to have hearing impairment in their right ear and 39.4% (82 out of 208) in their left ear, when they were examined during exposure to occupational noise [after at least 4 hr from entering the same shift].

In Table 3.6, a total of 26.7% (55 out of 208) of the selected workers were classified to have hearing impairment according to NIOSH and ASHA (1998) [average of hearing levels in either one or both ears exceeds 25 dB(A) at 1000, 2000, 3000, and 4000 Hz] in their right ear and 30.8% (64 out of 208) in their left ear, when they were examined before exposure to occupational noise. Otherwise, 46.6% (97 out of 208) of the selected workers were classified to have hearing impairment in their right ear and 45.2% (94 out of 208) in their left ear, when they were examined during exposure to occupational noise.

From Table 3.7, a total of 81 (38.9%) and 78 (37.5%) of the examined workers were classified to have hearing impairment according to EPA (1974) [average of hearing levels in either one or both ears exceeds 25 dB(A) at 500, 1000, and 2000 Hz] in their right and left ears respectively, when they were examined before exposure to occupational noise. In other respect, 113 (54.3%) and 119 (57.2%) of the examined workers were classified to have hearing impairment in their right and left ears respectively, when they were examined during exposure to occupational noise.

Percentage of degrees of hearing impairment in right and left ears of selected workers, when they were examined before and during exposure to occupational noise in the industrial plants [according to OSHA, NIOSH & ASHA, and EPA's definition of hearing impairment] is graphically displayed in Figs. 3.1 - 3.6.

Figures 3.1-3.6 show that there is a significant interaction between a percentage of hearing impairment in both ears of subjects and occupational noise levels, age, and duration of employment. These figures also showed that there are significant shifts in percentage of hearing impairment in both ears in different industrial plants shortly before exposure and during exposure of at least 4 hours of relatively high occupational noise.

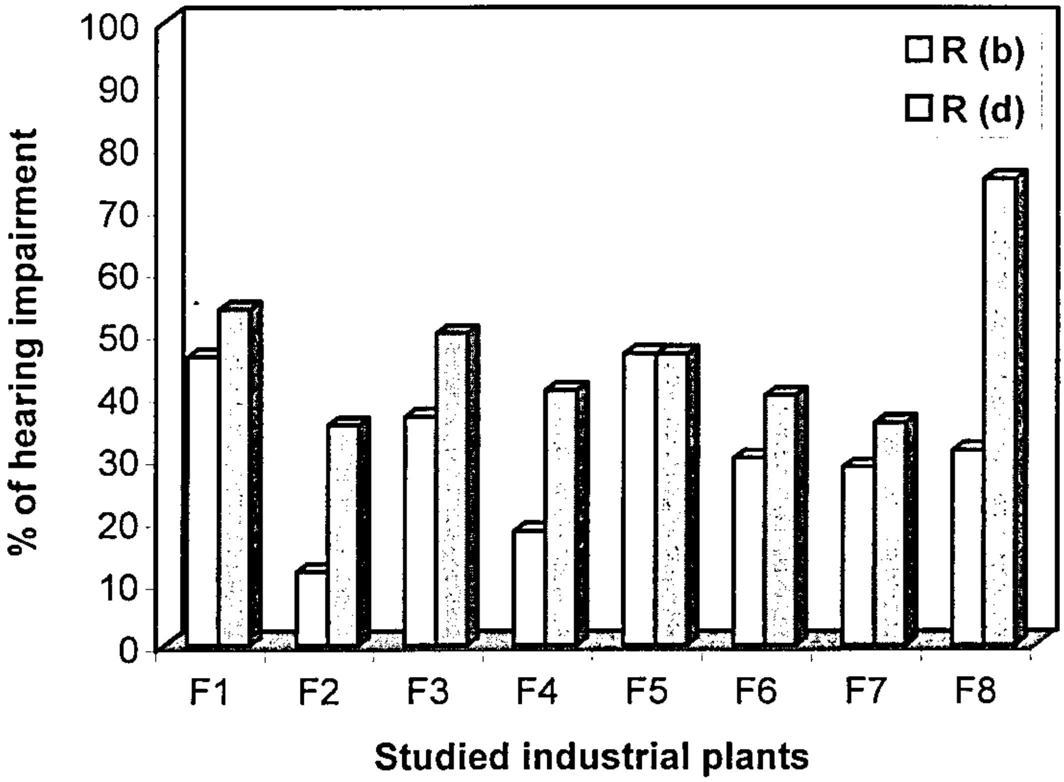


Fig. 3.1. Percentage of degrees of hearing impairment in right ear (R) of subjects before (b) and during (d) exposure to occupational noise in each studied industrial plant [according to OSHA's definition of hearing impairment].

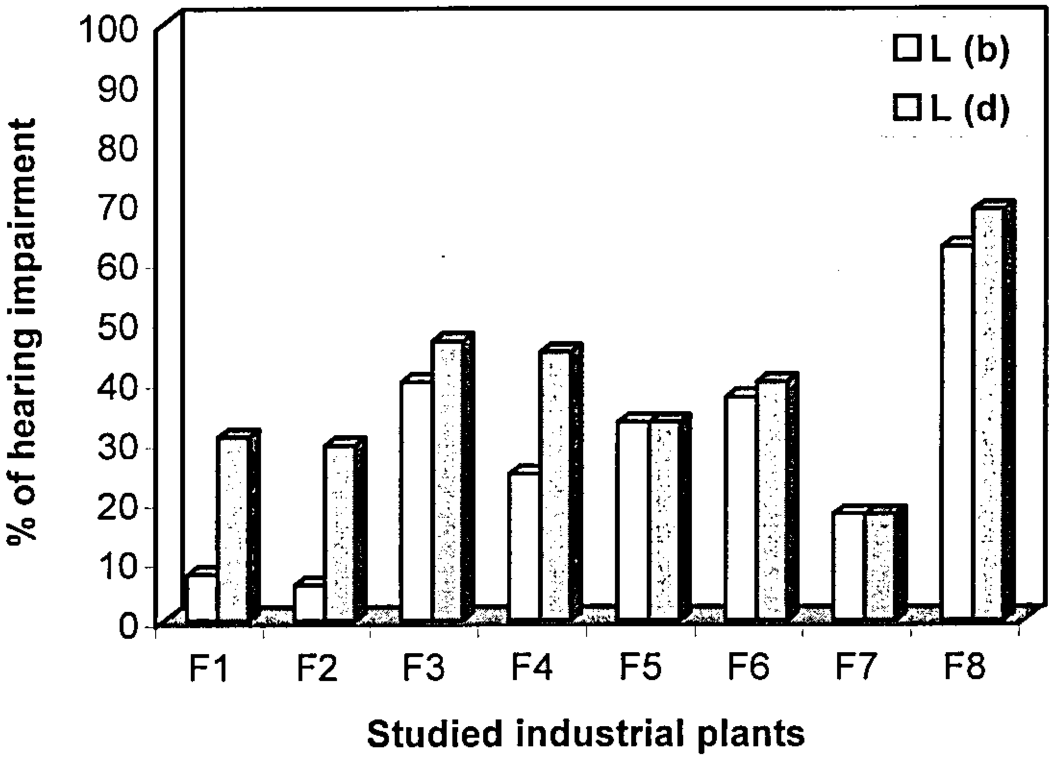


Fig. 3.2. **Percentage of degrees of hearing impairment in left ear (L) of subjects before (b) and during (d) exposure to occupational noise in each studied industrial plant [according to OSHA's definition of hearing impairment].**

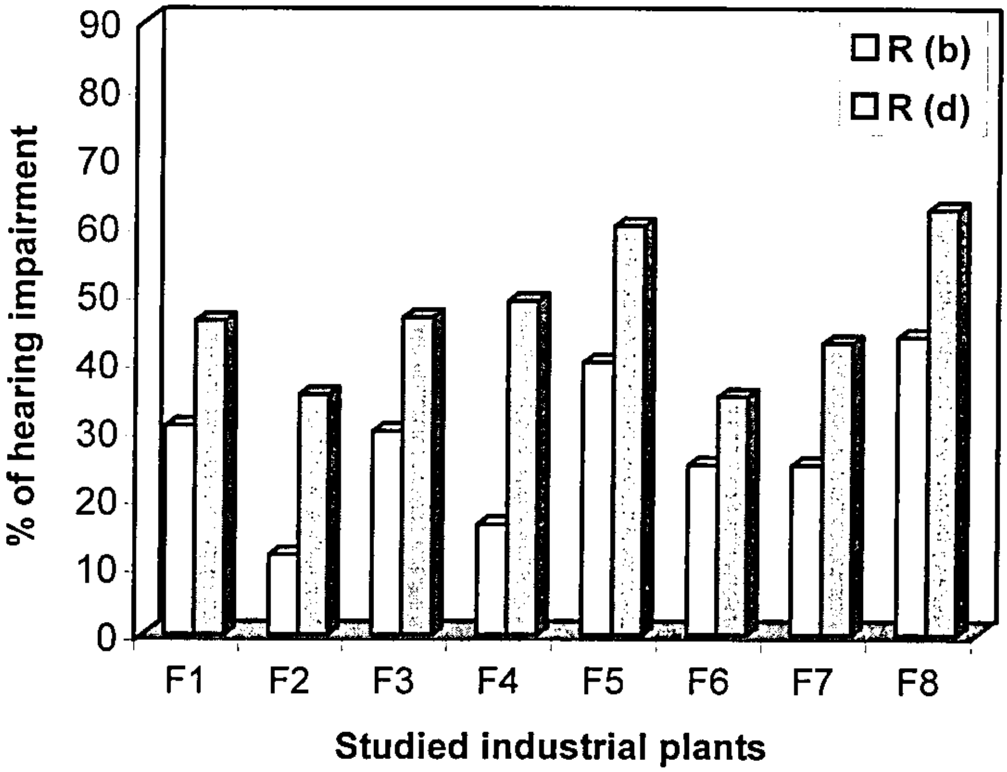


Fig. 3.3. Percentage of degrees of hearing impairment in right ear (R) of subjects before (b) and during (d) exposure to occupational noise in each studied industrial plant [according to NIOSH and ASHA's definition of hearing impairment].

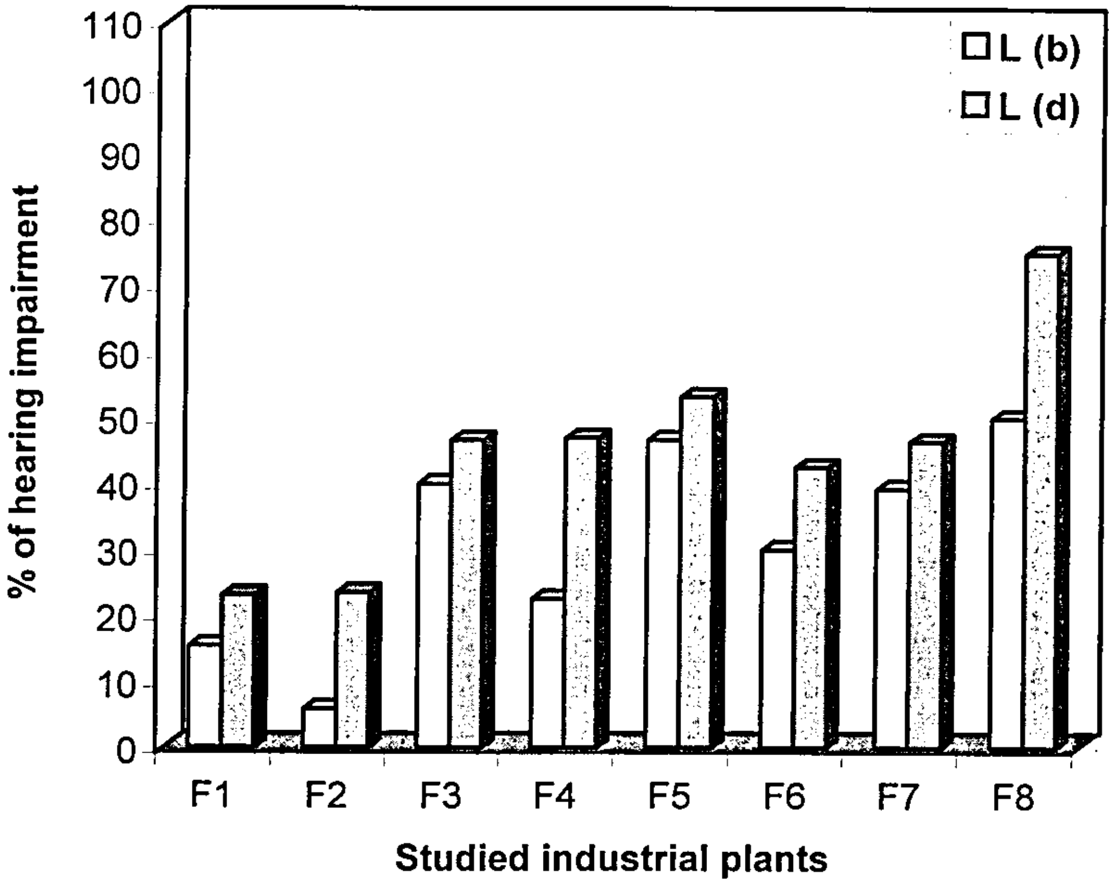


Fig. 3.4. Percentage of degrees of hearing impairment in left ear (L) of subjects before (b) and during (d) exposure to occupational noise in each studied industrial plant [according to NIOSH and ASHA's definition of hearing impairment].

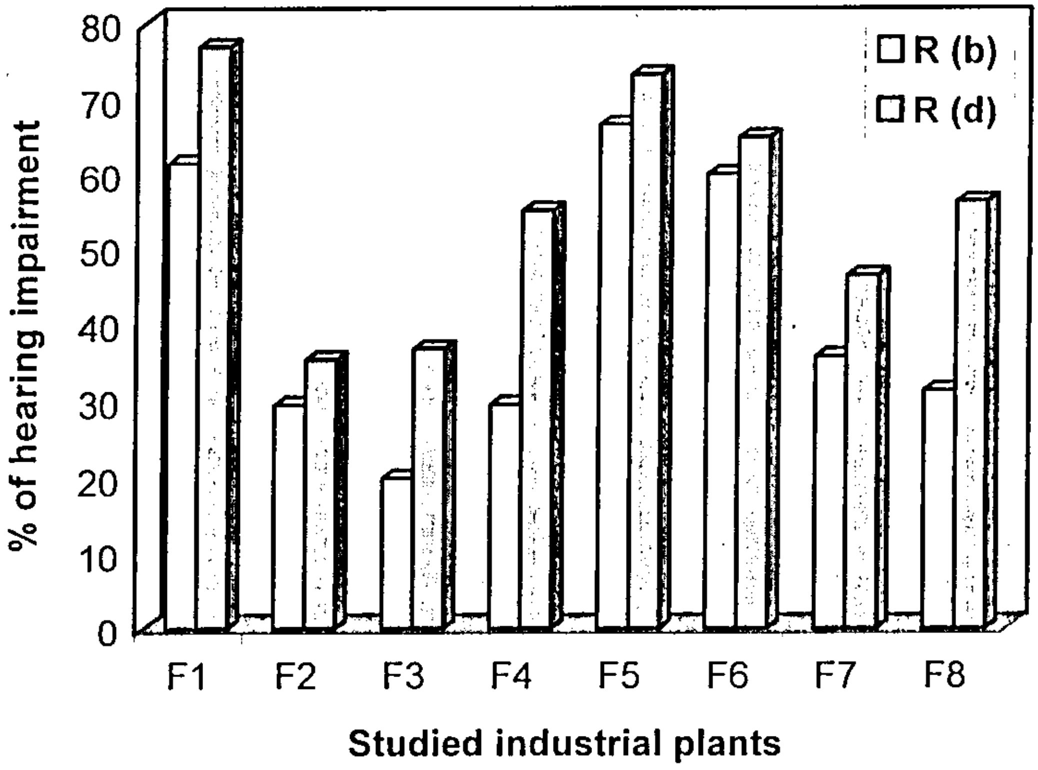


Fig. 3.5. Percentage of degrees of hearing impairment in right ear (R) of selected workers before (b) and during (d) exposure to occupational noise in each industrial plant [according to EPA's definition of hearing impairment].

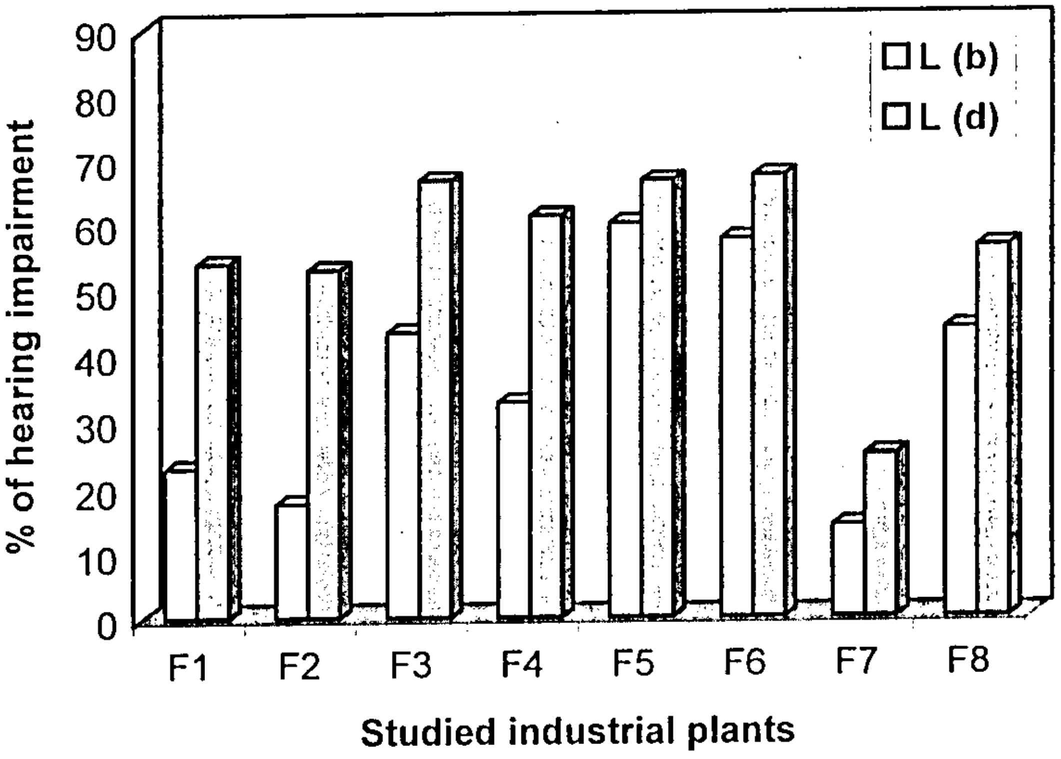


Fig. 3.6. Percentage of degrees of hearing impairment in left ear (L) of selected workers before (b) and during (d) exposure to occupational noise in each industrial plant [according to EPA's definition of hearing impairment].

The results of the audiometric examinations showed that the hearing threshold levels (HTL) were significantly higher at most frequencies. Significant interactions were found between several degrees of hearing impairment and levels of noise exposure. In Figures 3.7 - 3.9, the hearing threshold levels (HTL) of left and right ears for different subjects were plotted as a function of frequency. These figures showed the relationship between means of hearing threshold levels (HTL) of right and left ears of subjects according to different frequencies, before and during exposure to occupational noise in Vegetable Oils, Arabic Paints, and Cans Factory as a significant sample.

Figures 3.7 - 3.9 showed that there are significant hearing threshold shifts in right and left ears of subjects in different locations, shortly before exposure to occupational noise (pre-exposure) and during exposure of at least 4 hours from the beginning of morning shift.

Comparison of the different age groups showed that the hearing threshold levels were significantly higher among the oldest subjects [41 – 45 yr. > 36 – 40 yr. > 31 – 35 yr. > 25 – 30 yr.] (Fig. 3.10).

Multiple comparison of the different duration of employment groups showed that deterioration in hearing became prominent in the subjects with the longest duration of employment [18 – 25 yr. > 10 – 17 yr. > 2 – 9 yr.] (Fig. 3.11).

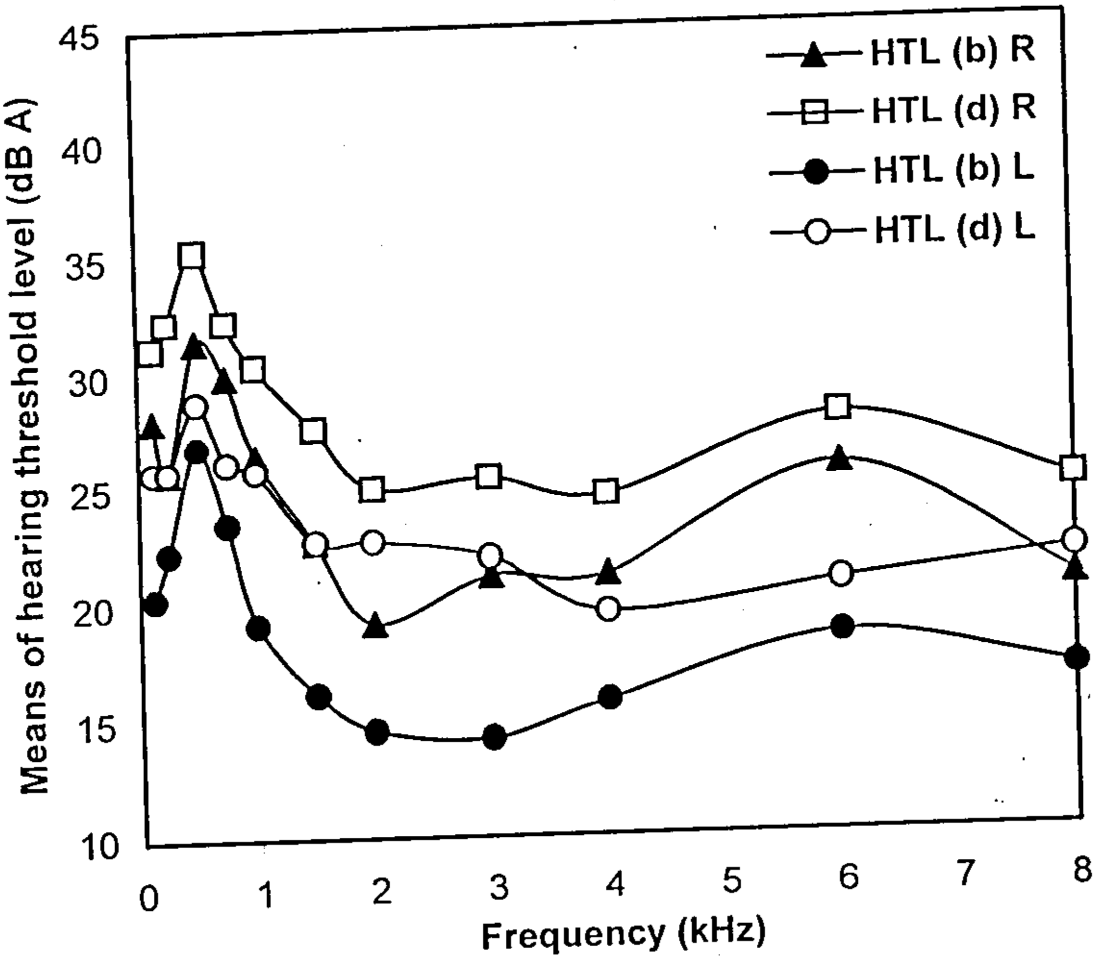


Fig. 3.7. Mean values of hearing threshold level (HTL) of right (R) and left (L) ears before (b) and during (d) exposure to occupational noise in Vegetable Oils Factory according to different frequencies.

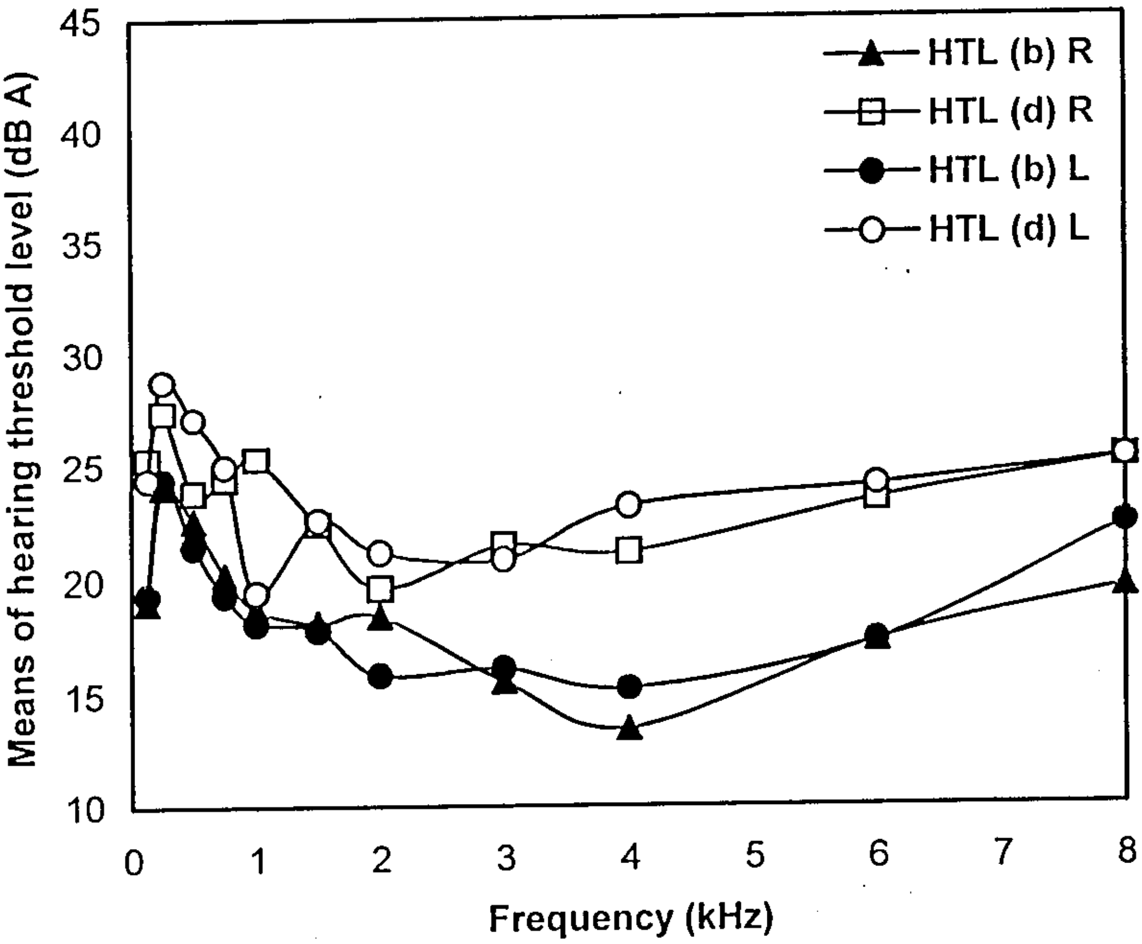


Fig. 3.8. Mean values of hearing threshold level (HTL) of right (R) and left (L) ears before (b) and during (d) exposure to occupational noise in Arabic Paints Factory according to different frequencies.

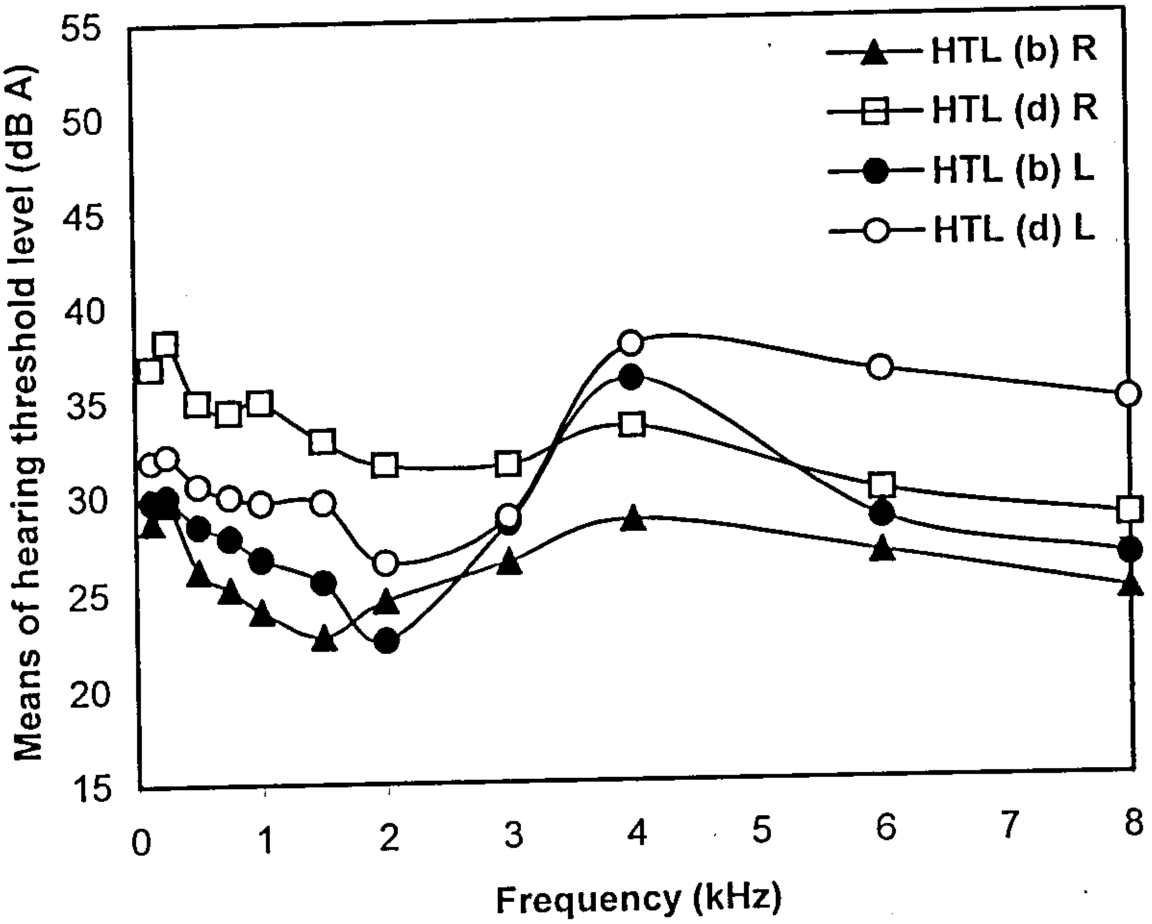


Fig. 3.9. Mean values of hearing threshold level (HTL) of right (R) and left (L) ears before (b) and during (d) exposure to occupational noise in Cans Factory according to different frequencies.

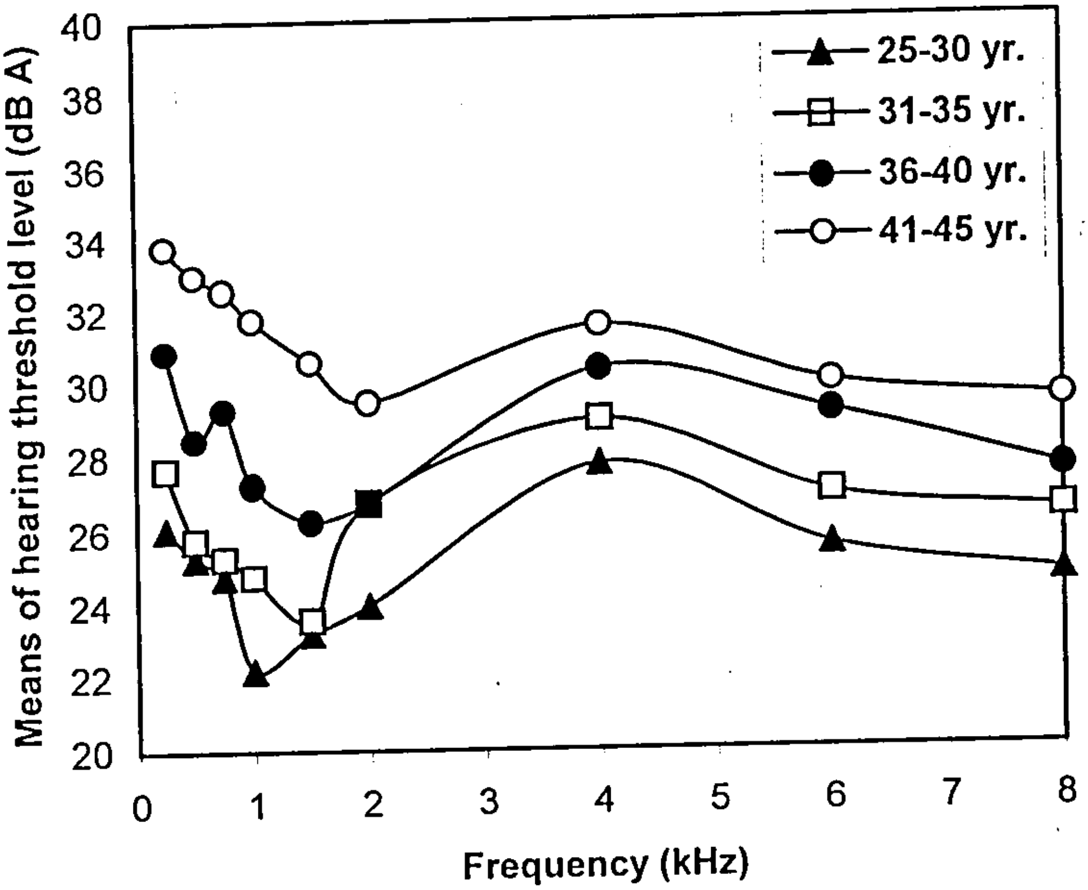


Fig. 3.10. Mean values of hearing threshold level (HTL) of right ear (R) of subjects according to different frequencies by different age groups. Age groups 25 – 30 yr., 31 – 35 yr., 36 – 40 yr., and 41 – 45 yr.

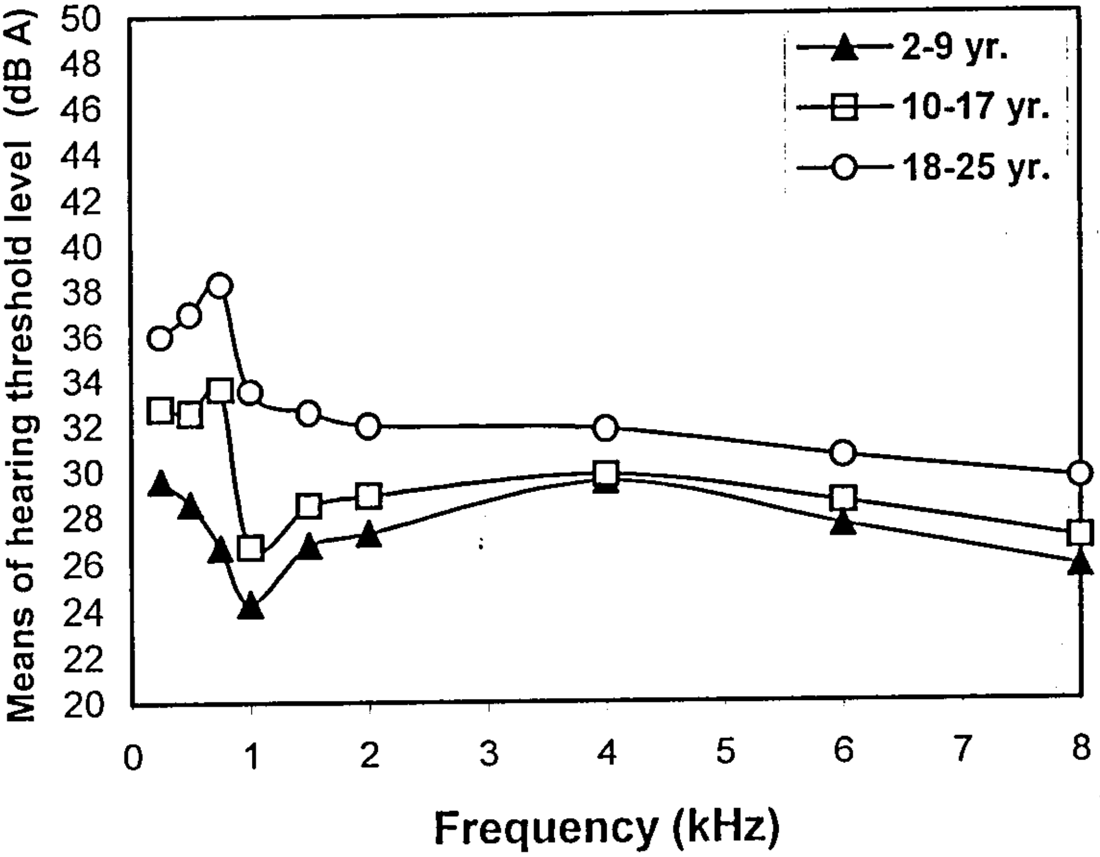


Fig. 3.11. Mean values of hearing threshold level (HTL) of right ear (R) of subjects according to different frequencies by different duration of employment groups.

Duration of employment groups 2 – 9 yr., 10 – 17 yr., and 18 - 25 yr.

3.4 Relationships between arterial blood pressure (systolic and diastolic), pulse rate, hearing threshold levels of subjects, and sound pressure levels in the studied industrial plants

Results of sound pressure levels (SPL), blood pressure, and audiometric examinations showed that there is strong positive correlation (Pearson Correlation Coefficient) between sound pressure levels (SPL) as an independent variable and pulse rate (P.R), systolic and diastolic blood pressure (SBP & DBP), and hearing threshold levels (HTL) at most frequencies as dependent variables (see Table 3.8).

Paired sample tests of pulse rate (P.R), systolic and diastolic blood pressure (SBP & DBP), and hearing threshold levels (HTL) in both ears were used to examine if there is shifting of these measurements after exposure to occupational noise level. All of these relationships are presented in Table 3.9.

Figures 3.12 - 3.14 display relationships between mean values of pulse rate (P.R), systolic and diastolic blood pressure (SBP & DBP) of subjects, and sound pressure levels (SPL) in each studied industrial plant.

Table 3.8. Pearson correlation coefficient between sound pressure levels (SPL) in dB(A) and arterial blood pressure (SBP and DBP), pulse rate (P.R), and hearing threshold levels (HTL) at different frequencies.

Independent variable, dB(A)	Dependent variables	Pearson correlation coefficient	Probability (P)
SPL	P.R	0.748	0.033*
SPL	SBP	0.734	0.038*
SPL	DBP	0.775	0.024*
SPL	R 125 Hz	0.603	0.114
SPL	L 125 Hz	0.769	0.026*
SPL	R 250 Hz	0.883	0.004**
SPL	L 250 Hz	0.366	0.372
SPL	R 500 Hz	0.910	0.002**
SPL	L 500 Hz	0.556	0.152
SPL	R 750 Hz	0.841	0.009**
SPL	L 750 Hz	0.487	0.221
SPL	R 1000 Hz	0.841	0.009**
SPL	L 1000 Hz	0.841	0.009**
SPL	R 1500 Hz	0.829	0.011*
SPL	L 1500 Hz	0.818	0.013*
SPL	R 2000 Hz	0.606	0.111
SPL	L 2000 Hz	0.465	0.246
SPL	R 3000 Hz	0.366	0.372
SPL	L 3000 Hz	0.818	0.013*
SPL	R 4000 Hz	0.776	0.024*
SPL	L 4000 Hz	0.705	0.048*
SPL	R 6000 Hz	0.829	0.011*
SPL	L 6000 Hz	0.938	0.001**
SPL	R 8000 Hz	0.326	0.431
SPL	L 8000 Hz	0.617	0.103

SPL: Sound pressure level in dB(A), P.R: Pulse rate (beats/min), SBP: Systolic blood pressure (mmHg), DBP: Diastolic blood pressure (mmHg), R: Right ear, L: Left ear, 125 Hz – 8000 Hz: Frequencies which were used to detect the hearing levels of the subjects. *: Significant ($P < 0.05$), **: Highly significant ($P < 0.01$).

Table 3.9. Paired samples correlation of all studied variables before (b) and during (d) exposure to occupational noise in all studied industrial plants.

Paired variables	Pearson correlation coefficient	Probability (P)
P.R (b) & P.R (d)	0.414	0.307
SBP (b) & SBP (d)	0.884	0.004**
DBP (b) & DBP (d)	0.875	0.004**
R 125 Hz (b) & R 125 Hz (d)	0.720	0.044*
L 125 Hz (b) & L 125 Hz (d)	0.772	0.025*
R 250 Hz (b) & R 250 Hz (d)	0.802	0.017*
L250 Hz (b) & L 250 Hz (d)	0.673	0.067
R500 Hz (b) & R 500 Hz (d)	0.850	0.007**
L500 Hz (b) & L 500 Hz (d)	0.802	0.017*
R750 Hz (b) & R 750 Hz (d)	0.659	0.075
L750 Hz (b) & L 750 Hz (d)	0.772	0.025*
R1000 Hz (b) & R 1000 Hz (d)	0.401	0.325
L1000 Hz (b) & L 1000 Hz (d)	0.630	0.094
R1500 Hz (b) & R 1500 Hz (d)	-0.080	0.850
L1500 Hz (b) & L 1500 Hz (d)	0.392	0.337
R2000 Hz (b) & R 2000 Hz (d)	0.720	0.044*
L2000 Hz (b) & L 2000 Hz (d)	0.116	0.785
R3000 Hz (b) & R 3000 Hz (d)	0.494	0.213
L3000 Hz (b) & L 3000 Hz (d)	0.795	0.018*
R4000 Hz (b) & R 4000 Hz (d)	0.892	0.003**
L4000 Hz (b) & L 4000 Hz (d)	0.722	0.043*
R6000 Hz (b) & R 6000 Hz (d)	0.761	0.028*
L6000 Hz (b) & L 6000 Hz (d)	0.776	0.024*
R8000 Hz (b) & R 8000 Hz (d)	0.887	0.003**
L8000 Hz (b) & L 8000 Hz (d)	0.914	0.001**

P.R: Pulse rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, R: Right ear, L: Left ear, b: Before exposure to environmental noise, d: During exposure to environmental noise, and 125 Hz – 8000 Hz: Frequencies which were used to detect the hearing levels of the subjects. *: Significant ($P < 0.05$), **: Highly significant ($P < 0.01$).

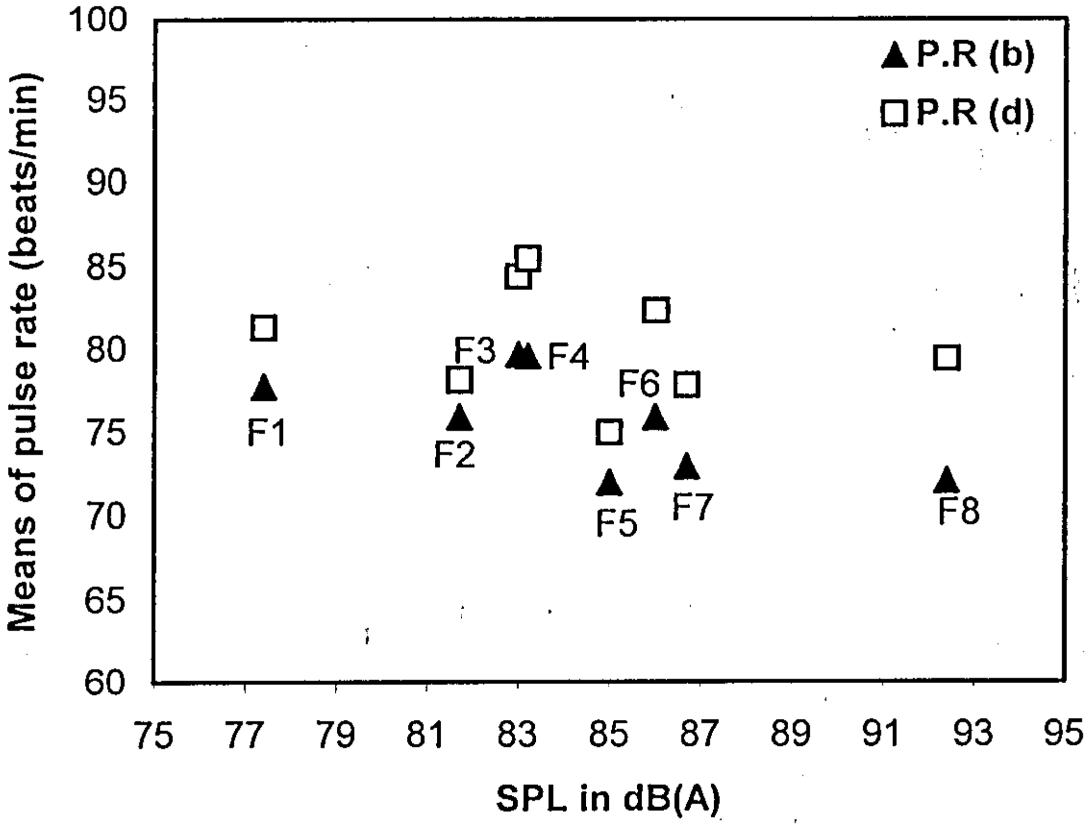


Fig. 3.12. Mean values of pulse rate (P.R) of subjects according to sound pressure levels (SPL) in each studied industrial plant.

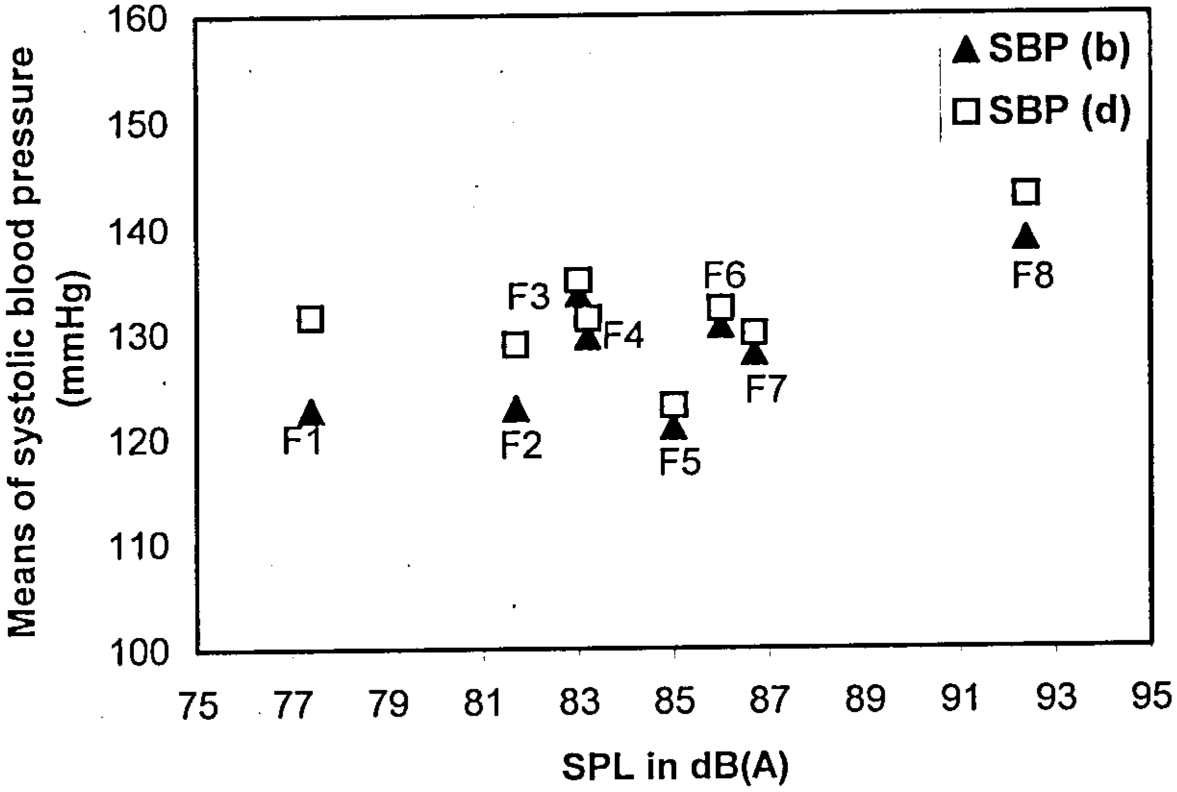


Fig. 3.13. Mean values of systolic blood pressure (SBP) of subjects according to sound pressure levels (SPL) in each studied industrial plant.

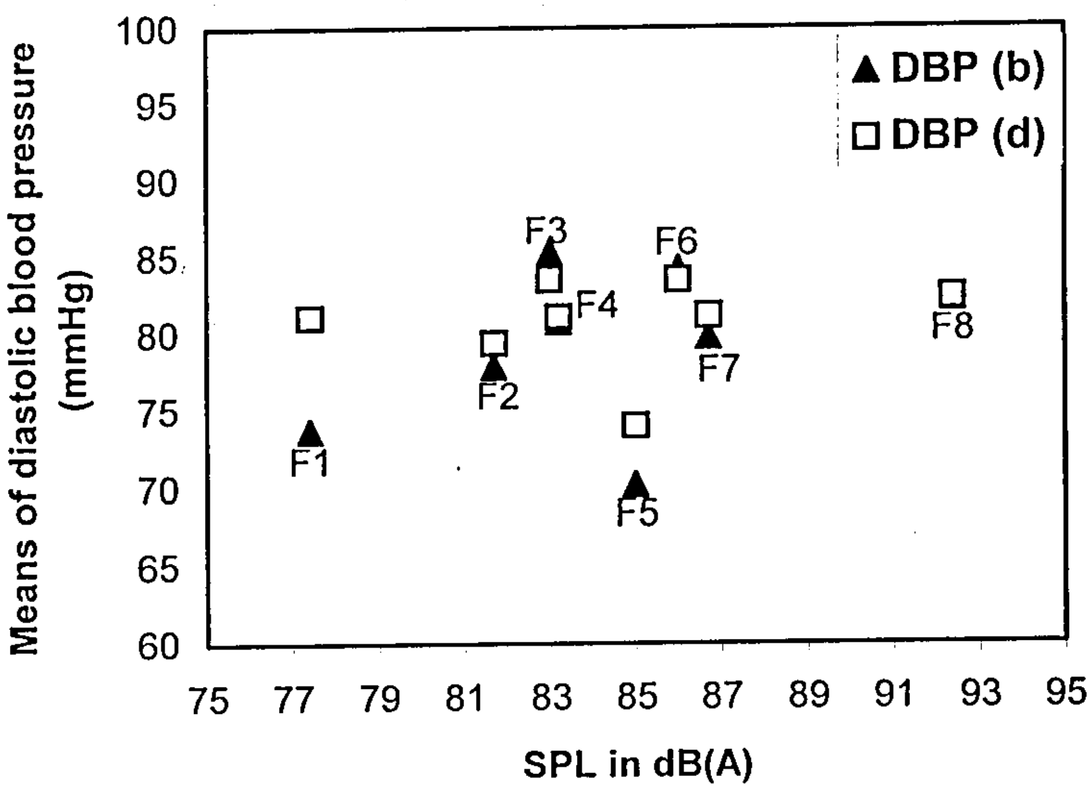


Fig. 3.14. Mean values of diastolic blood pressure (DBP) of subjects according to sound pressure levels (SPL) in each studied industrial plant.

3.5 Relationships between arterial blood pressure (systolic and diastolic), pulse rate, and age of subjects in the studied industrial plants

Figures 3.15 - 3.17 display relationships between mean values of arterial blood pressure (SBP & DBP), pulse rate (P.R), and age of subjects in each studied industrial plant.

These figures showed that there are significant interactions between mean values of pulse rate (P.R), systolic and diastolic blood pressure (SBP & DBP), and age of subjects in each studied industrial plant.

Comparison of the different age groups showed that the mean values of pulse rate, systolic and diastolic blood pressure were significantly higher among the oldest subjects [41 – 45 yr. > 36 – 40 yr. > 31 – 35 yr. > 25 – 30 yr.] (Figs. 3.18 & 3.19).

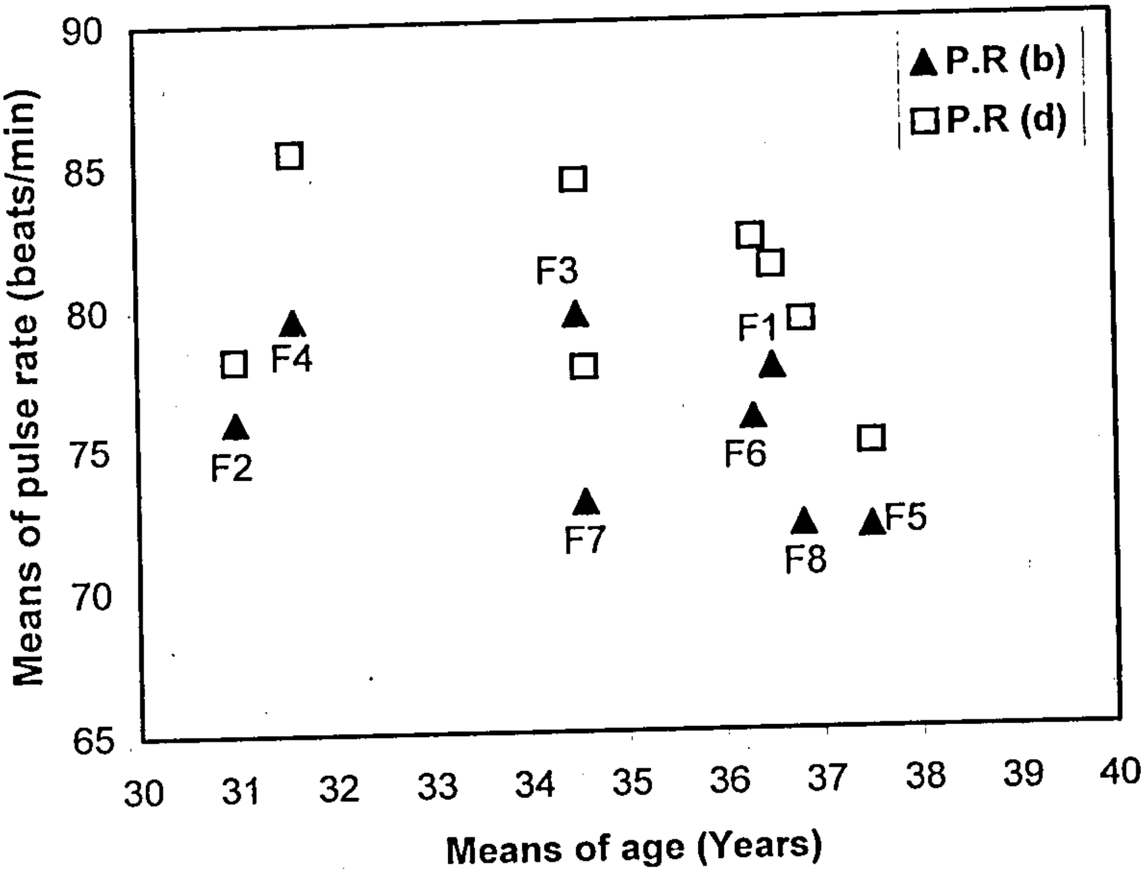


Fig. 3.15. Mean values of pulse rate (P.R) of subjects by means of age in each studied industrial plant.

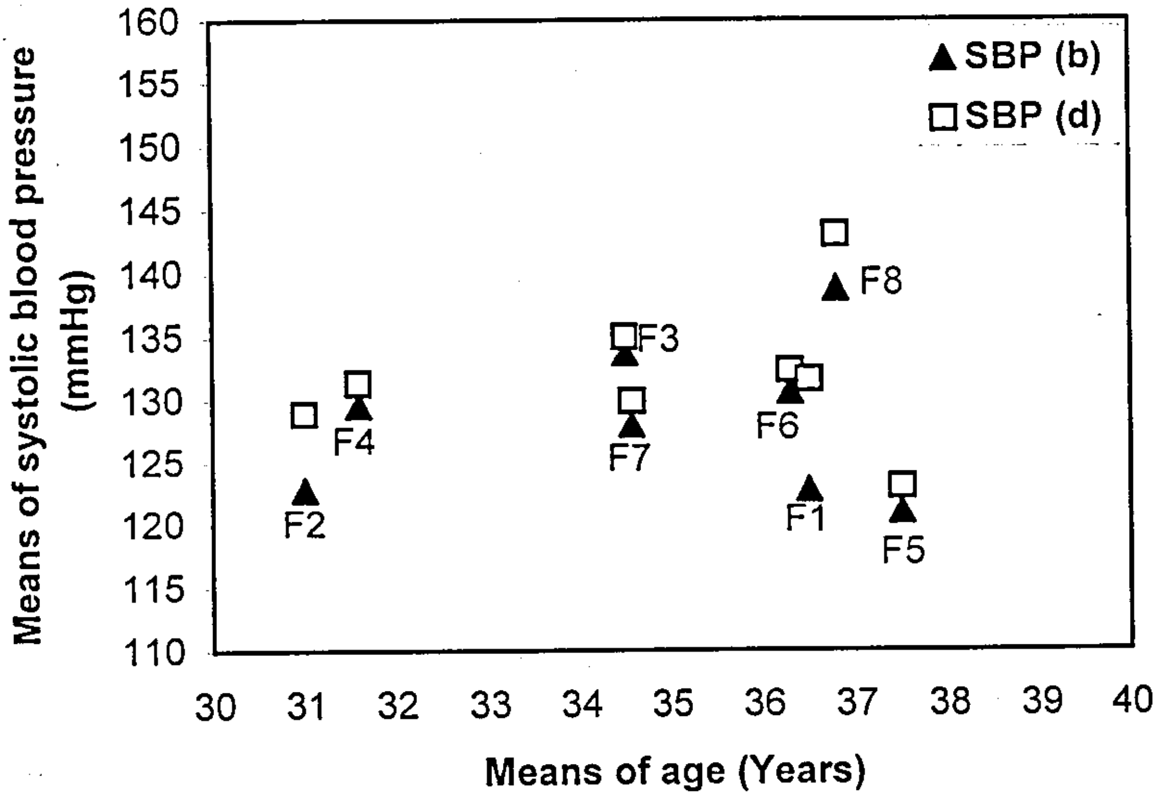


Fig. 3.16. Mean values of systolic blood pressure (SBP) of subjects by means of age in each studied industrial plant.

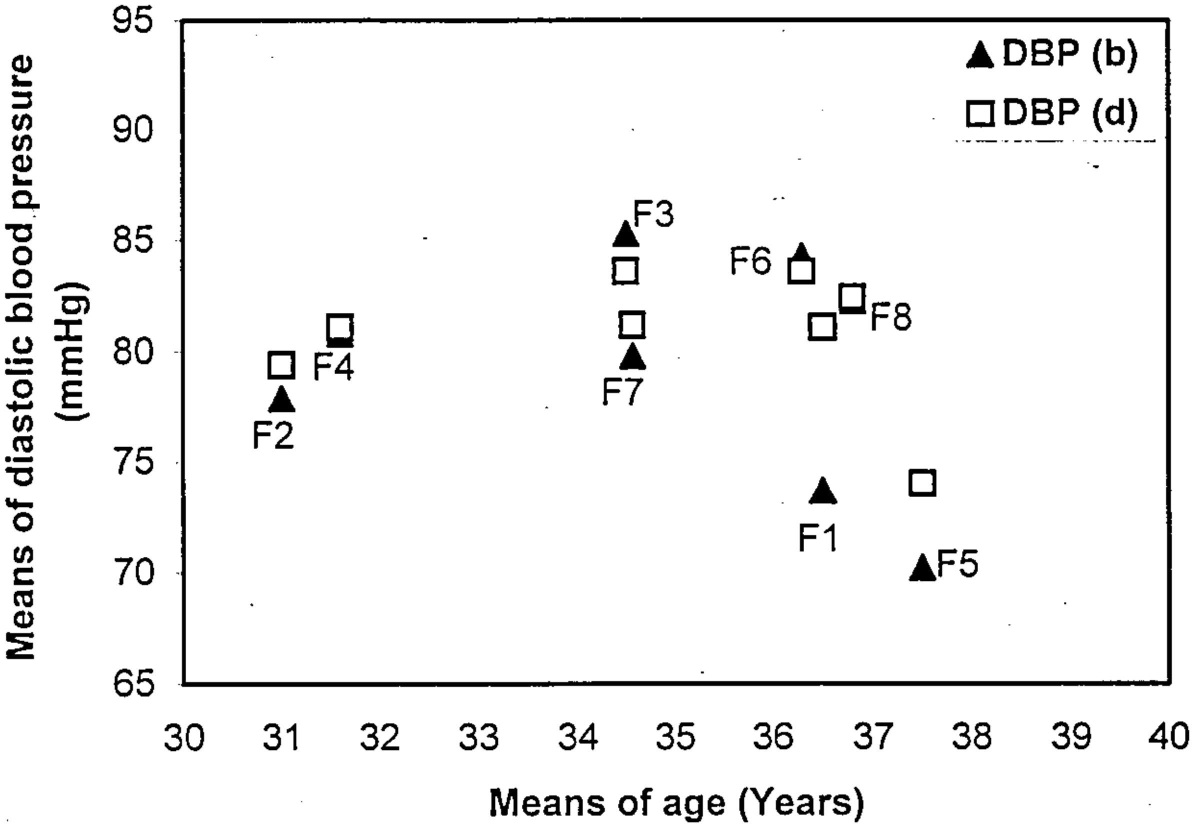


Fig. 3.17. Mean values of diastolic blood pressure (DBP) of subjects by means of age in each studied industrial plant.

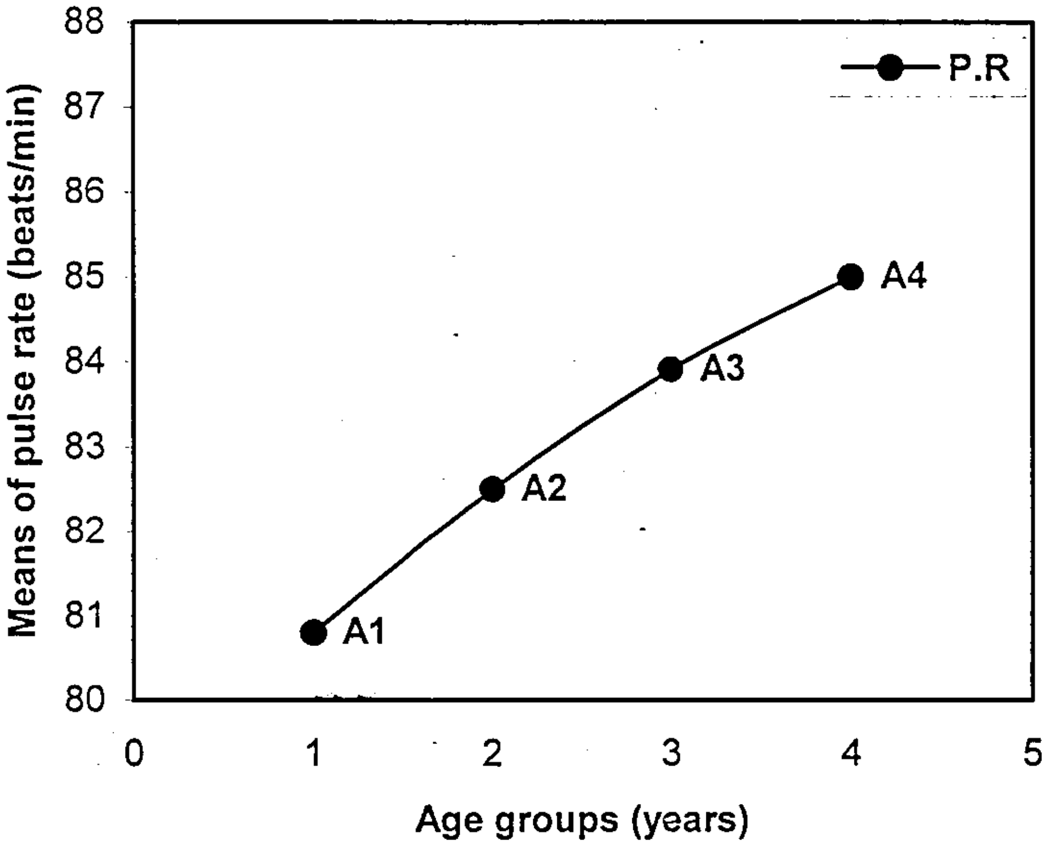


Fig. 3.18. Mean values of pulse rate (P.R) of all selected workers (during-exposure) according to different age groups.

Age groups A1: 25 – 30 yr., A2: 31 – 35 yr., A3: 36 – 40 yr., and A4: 41 – 45 yr.

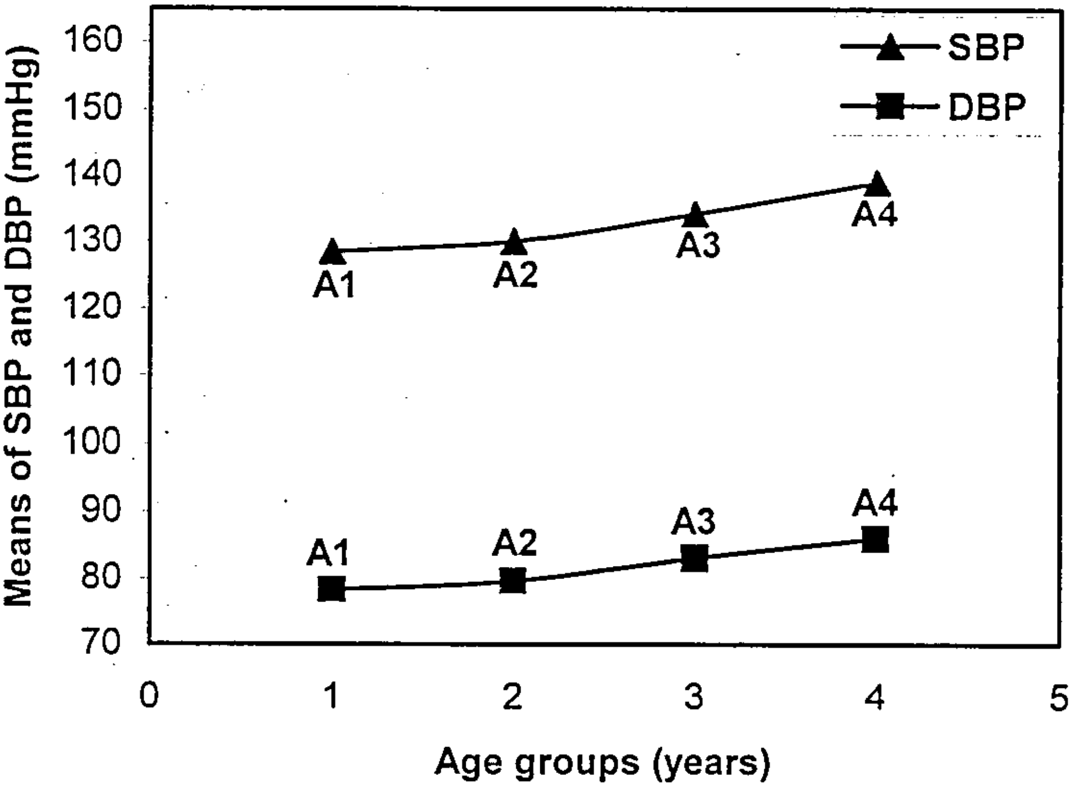


Fig. 3.19. Mean values of systolic and diastolic blood pressure (SBP & DBP) of all selected workers (during-exposure) according to different age groups.

Age groups A1: 25 – 30 yr., A2: 31 – 35 yr., A3: 36 – 40 yr., and A4: 41 – 45 yr.

3.6 Relationships between arterial blood pressure (systolic and diastolic), pulse rate, and duration of employment of subjects in the studied industrial plants

Figures 3.20 - 3.22 display relationships between mean values of systolic and diastolic blood pressure (SBP & DBP), pulse rate (P.R), and duration of employment of subjects in each studied industrial plant.

These figures showed that there are significant interactions between mean values of pulse rate (P.R), systolic and diastolic blood pressure (SBP & DBP), and duration of employment of subjects in each studied industrial plant.

Comparison of the different duration of employment groups showed that the mean values of pulse rate, systolic and diastolic blood pressure were significantly higher among the subjects with the longest duration of employment [18 – 25 yr. > 10 – 17 yr. > 2 – 9 yr.] (Figs. 3.23 & 3.24).

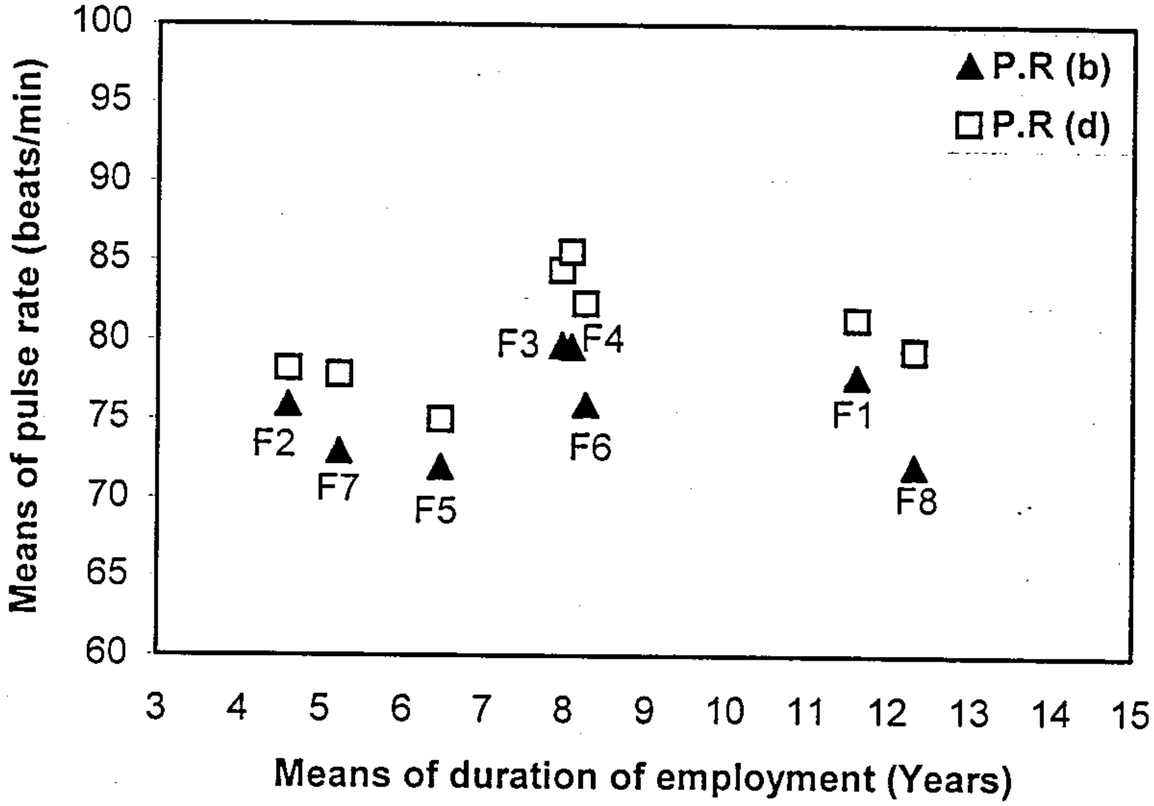


Fig. 3.20. Mean values of pulse rate (P.R) of subjects by means of duration of employment in each studied industrial plant.

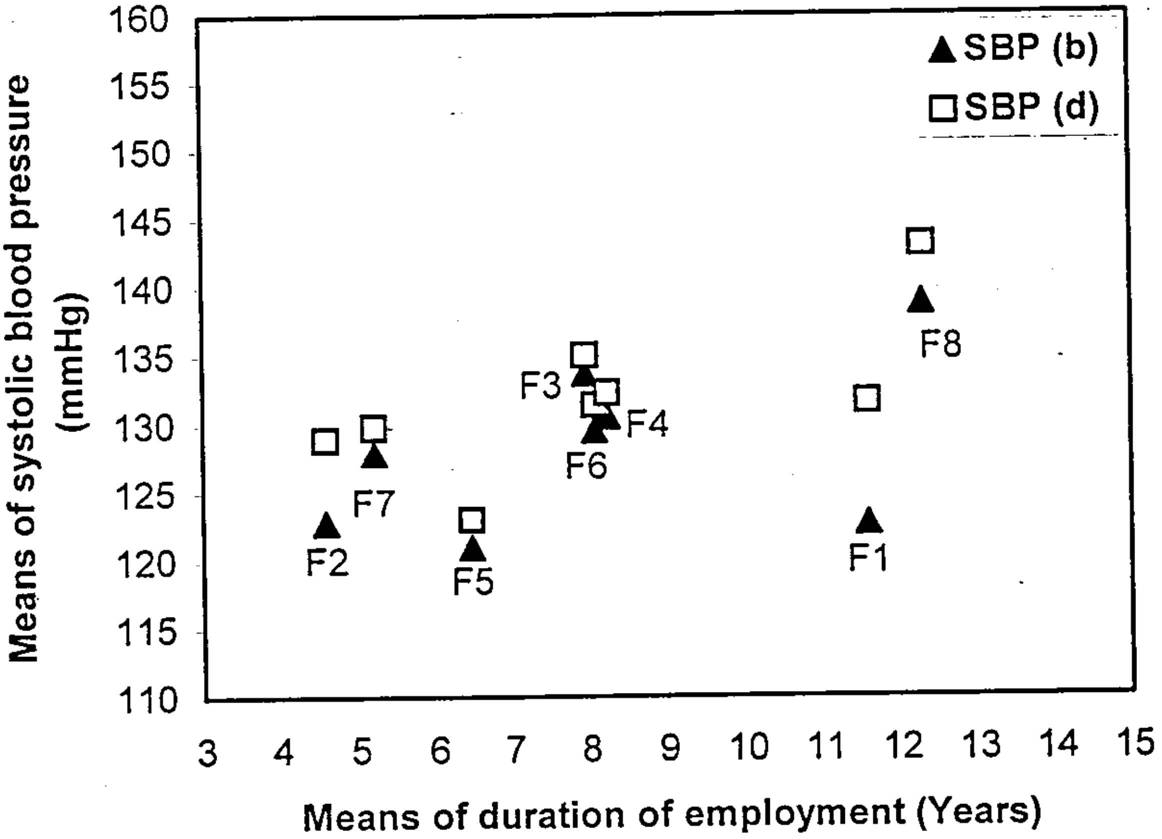


Fig. 3.21. Mean values of systolic blood pressure (SBP) of subjects by means of duration of employment in each studied industrial plant.

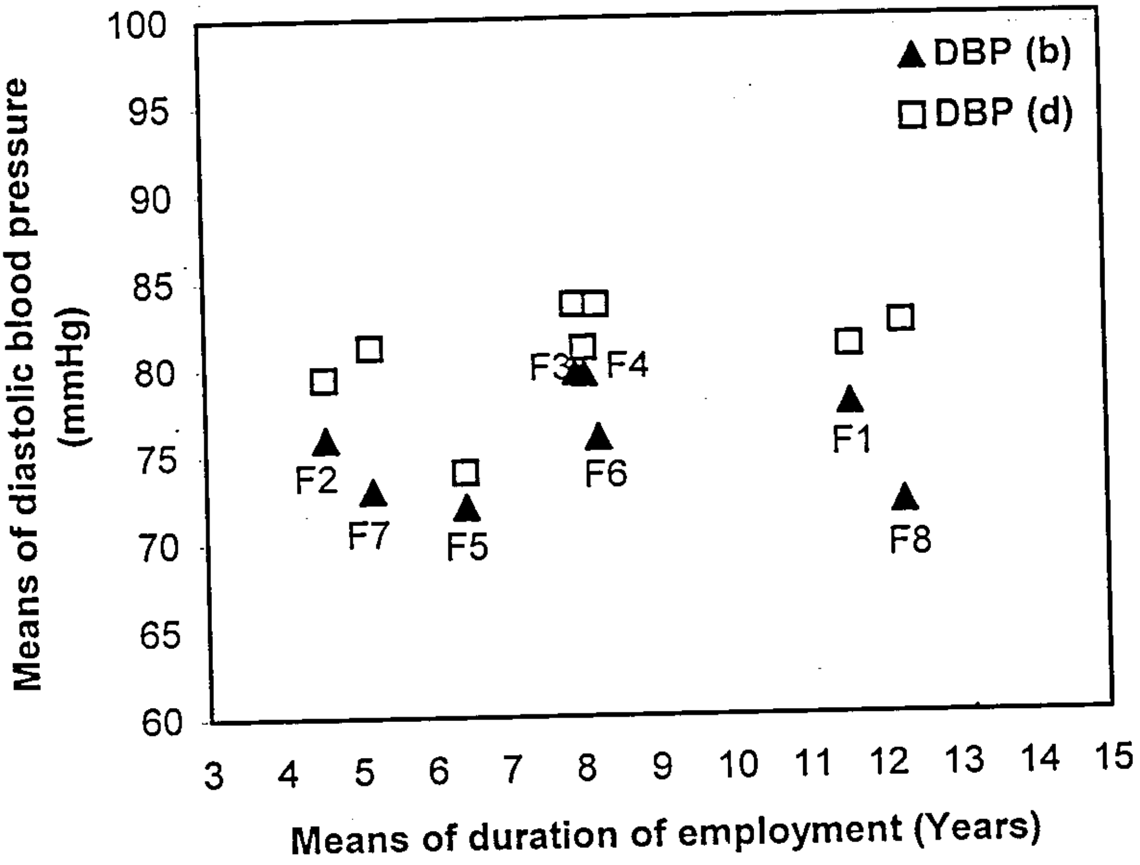


Fig. 3.22. Mean values of diastolic blood pressure (DBP) of subjects by means of duration of employment in each studied industrial plant.

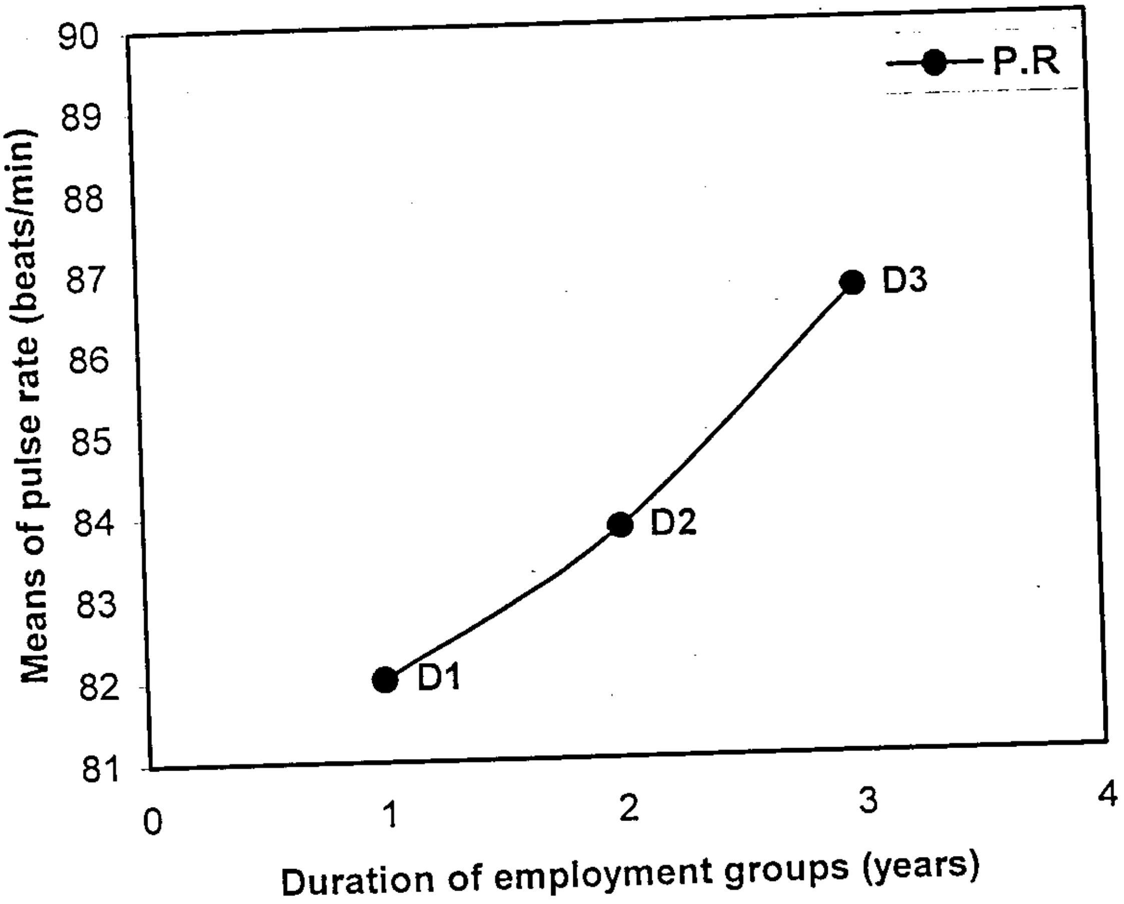


Fig. 3.23. Mean values of pulse rate (P.R) of subjects (during-exposure) according to different duration of employment groups.

Duration of employment groups D1: 2 – 9 yr., D2: 10 – 17 yr., and D3: 18 – 25 yr.

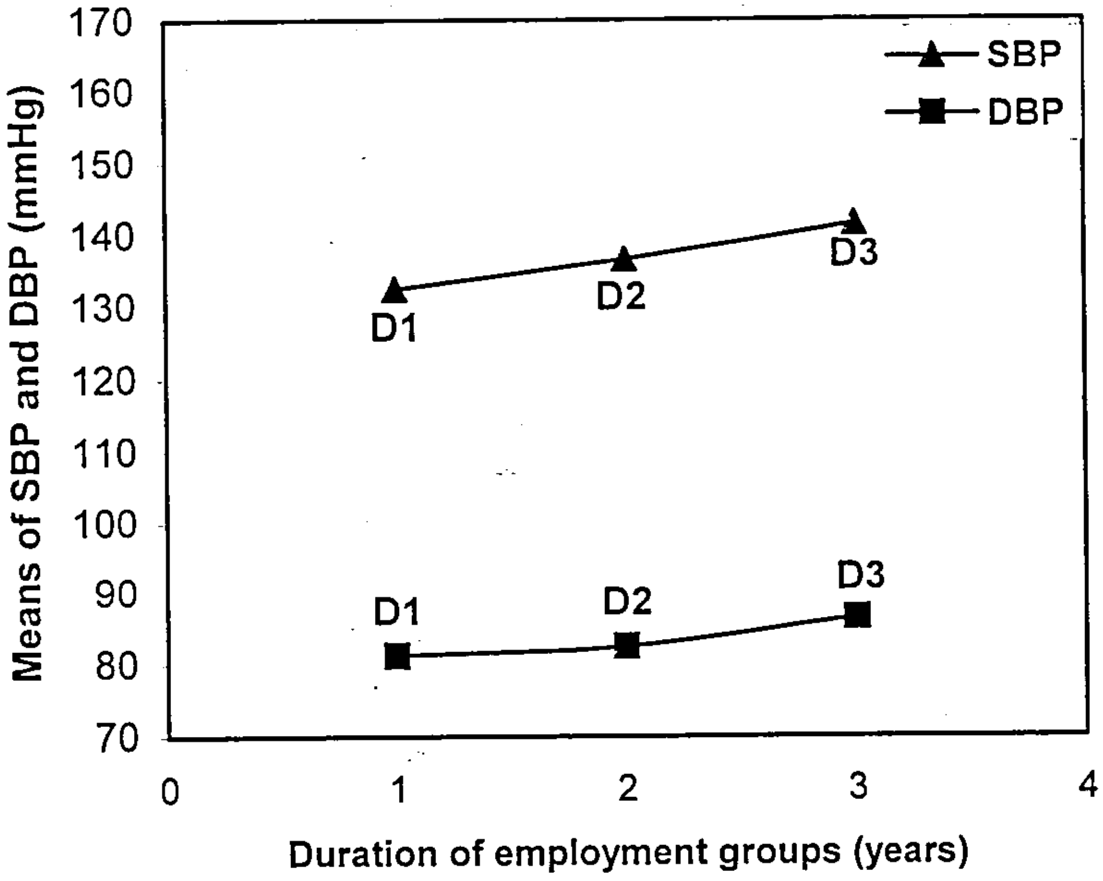


Fig. 3.24. Mean values of systolic and diastolic blood pressure (SBP & DBP) of subjects (during-exposure) according to different duration of employment groups.

Duration of employment groups D1: 2 – 9 yr., D2: 10 – 17 yr., and D3: 18 – 25 yr.

3.7 Questionnaires results

Two questionnaires (Appendices B.5 & B.6) were administrated during this survey to collect the subjective responses of the selected industrial plants' workers toward their acoustical environment and the general acoustical information of the studied industrial plants.

The first one (Appendix B.5) was about conditions of working environment (including the nature of industry, production lines and shifts, number of workers and machines, years of the machines under working, location of each factory, and other environmental conditions). The results of this questionnaire were summarized in Appendix B.1. The second one (Appendix B.6) was distributed on all selected workers, contained the study variables (such as age, sex, daily and weekly working hours, duration of employment, health status, and reactions of workers to environmental conditions).

Question (1) in the second questionnaire, asked all selected workers to rate their feel of symptoms (nervous tension, low concentration, nausea, dizziness, migraine headache, hearing loss, and muscle contraction) during working hours, using a point scale which is commonly used in social survey (no feel, light, fairly, and extremely). Summery of percentages of these symptom levels in all selected industrial plants is presented in Table 3.10.

Table 3.10. Percentages of feeling of nervous tension, low concentration, nausea, dizziness, migraine headache, hearing impairment, and muscle contraction in the whole study population.

Symptoms	Levels*	%
Nervous Tension	1	36.5 (76/208)
	2	52.4 (109/208)
	3	9.1 (19/208)
	4	2.0 (4/208)
Low Concentration	1	52.4 (109/208)
	2	42.3 (88/208)
	3	4.8 (10/208)
	4	0.5 (1/208)
Nausea	1	82.7 (172/208)
	2	16.4 (34/208)
	3	0.9 (2/208)
	4	-
Dizziness	1	81.7 (170/208)
	2	17.4 (36/208)
	3	0.9 (2/208)
	4	-
Migraine Headache	1	59.1 (123/208)
	2	35.6 (74/208)
	3	5.3 (11/208)
	4	-
Hearing Impairment	1	66.4 (138/208)
	2	30.3 (63/208)
	3	3.3 (7/208)
	4	-
Muscle Contraction	1	48.1 (100/208)
	2	40.9 (85/208)
	3	8.7 (18/208)
	4	2.3 (5/208)

*1: No feel, 2: Light, 3: Fairly, and 4: Extremely.

**Total of frequencies = 208 which is the number of selected workers.

Question (2) in the second questionnaire asked all selected workers about disease cases (such as: cardiovascular, blood pressure, hearing impairment, nervous tension, and sleep disturbance) before (b) and after (a) receiving the current job. Summary of percentages of these cases in all selected industrial plants is presented in Table 3.11.

Question (3) in the second questionnaire asked all selected workers about the work accidents. Summary of percentages of work accidents is presented in Table 3.12.

According to the results in Table 3.10, there is an association between exposure to high levels of occupational noise pollution in long-term duration and feeling of nervous tension, low concentration, nausea, dizziness, migraine headache, hearing impairment, and muscle contraction which are related to mental and physiological health effects.

The results in Table 3.11 showed that there are considerable differences between the percentage of feeling of mental (nervous tension, sleep disturbance) and physiological (hearing impairment) disease cases before and after receiving the current job. These results prove that there is a significant correlation between these disease cases and receiving work with high noise emission levels.

Results in Table 3.12 examined the relationship between occupational noise as a source of annoyance, stress and dissatisfaction, and work accidents.

Table 3.11. Percentages of hearing impairment, nervous tension, and sleep disturbance before (b) and after (a) receiving the current job in whole study population.

Symptoms		%	Symptoms	%
Hearing Impairment (b*)	Yes	-	Hearing Impairment (a**)	12.5 (26/208)
	No	100 (208/208)		87.5 (182/208)
Nervous Tension (b)	Yes	4.3 (9/208)	Nervous Tension (a)	39.9 (83/208)
	No	95.7 (199/208)		60.1 (125/208)
Sleep Disturbance (b)	Yes	6.3 (13/208)	Sleep Disturbance (a)	40.9 (85/208)
	No	93.7 (195/208)		59.1 (123/208)

* b: before receiving the current job, **a: after receiving the current job.

Table 3.12. Percentage of work accidents in each studied industrial plant.

Name of the Factory	Variable		%
Vegetable Oils (F1)	Work Accident	Yes	30.8 (4/13)
		No	69.2 (9/13)
Arabic Paints (F2)	Work Accident	Yes	11.8 (2/17)
		No	88.2 (15/17)
Al - Carton (F3)	Work Accident	Yes	40 (12/13)
		No	60 (18/13)
Al - Aqad (F4)	Work Accident	Yes	32.7 (16/49)
		No	67.3 (33/49)
Al - Andalus (F5)	Work Accident	Yes	20 (3/15)
		No	80 (12/15)
Al - Nasir (F6)	Work Accident	Yes	30 (12/40)
		No	70 (28/40)
Al - Arz (F7)	Work Accident	Yes	35.7 (10/28)
		No	64.3 (18/28)
Cans Factory(F8)	Work Accident	Yes	43.7 (7/16)
		No	56.3 (9/16)

CHAPTER FOUR

Discussion

An occupational noise exposure study was carried out at various working places in eight industrial plants in Nablus city. Equivalent continuous sound pressure levels (SPL) in dB(A) [L_{Aeq} - values] in all studied plants ranged from 77.4 to 92.4 dB(A), with an arithmetic mean value of 84.43 ± 4.34 dB(A) [mean ± SD]. The highest occupational noise level was observed at Cans factory [metal production] and the lowest at Vegetable Oils factory [food production] (Table 3.1).

Four of the eight studied industrial plants (50%) had occupational noise exposure $\geq$85 dB(A), 47.5% of whole study population are exposed to these levels. Three of the studied industrial plants (37.5%) had occupational noise ranged from 80 - $<$85 dB(A), 46.2% of the whole study population are exposed to these levels. One of the studied industrial plants (12.5%) had occupational noise exposure of 77.4 dB(A), 6.3% of study population are exposed to this noise level (Table 3.1).

The average working hours in all study locations is 11.25 hr/day; 10 hr/day 37.5 % of the studied industrial plants and 12 hr/day 62.5 % of them (Table 3.1). The working hours in all studied industrial plants are more than 8 hr/day as most international regulations recommended (EPA, 1974; NIOSH, 1998; OSHA, 1981).

Eighty-five dB(A) as an 8 hr time - weighted average (TWA), was determined by ANSI and NIOSH as a recommended exposure limit (REL) for occupational noise exposure (NIOSH, 1998). 90 dB(A) as an 8-hr TWA was recommended by OSHA (OSHA, 1981), WHO (Mato & Mufuruki, 1999) and ISO (Shaikh, 1999). 75 dB(A) as an 8 hr TWA was recommended by EPA (EPA, 1974). According to these different regulations, exposure at or above these levels is considered hazardous to human health (see Appendix A.8 for more information).

The overall results in this study indicated that various groups of workers are exposed to high occupational noise levels. The noise mapping performed at most studied industrial plants showed that for most part of working hours, the noise levels exceeded the permissible levels set by the international standards (Appendix A.8). Daily exposure of the workers to these levels of continuous noise put them at risk of developing noise-induced hearing loss (NIHL) and other physiological and mental disorders (NIOSH, 1998; WHO, 1999).

Noise-induced hearing loss (NIHL) is caused by exposure to high sound levels or duration that damage the hair cells of the cochlea. Initially, the noise exposure may cause a temporary threshold shift, that is a decrease in hearing sensitivity that typically returns to its former level within a few minutes to a few hours. Repeated exposures lead to a permanent threshold shift, which is an irreversible sensorineural hearing loss (NIOSH, 1998).

Results of the audiometric examinations showed that the hearing threshold levels (HTL) were significantly higher at most frequencies. The hearing threshold levels of different frequencies correlated positively [$p < 0.05$ & $p < 0.01$] with the occupational noise levels (Table 3.8). Significant interactions were found between percentage of several degrees of hearing impairment [according to ANSI, OSHA, NIOSH & ASHA, and EPA's definition] in both ears of subjects and occupational noise levels, age, and duration of employment (Tables 3.4 - 3.7 & Figs. 3.1-3.6). Previous studies that revealed strong causal relationships between noise exposure and hearing loss are well documented (Sharma *et al.*, 1998; Nguyen *et al.*, 1998; Wu *et al.*, 1998).

In addition, this study showed that there are significant hearing threshold shifts in the right and left ears of subjects in different locations shortly before exposure to occupational noise (pre-exposure) and during exposure of at least 4 hours from the beginning of morning shift (Figs. 3.7 - 3.9).

The profile of the hearing ability of the selected workers in this study, revealed that the length of employment and age of the subjects are an important factors in the development of hearing impairment. The significant interaction between age and noise exposure suggesting that the older workers may be more sensitive to noise exposure than younger workers (Fig. 3.10). The hearing threshold levels of workers employed for more than 10 years were worse than for those employed for a shorter period of time (Fig. 3.11). These findings conform to the results of other studies that showed the relationship between progression of hearing loss with continuous exposure (Gallo & Glorig, 1964; Nguyen *et al.*, 1998; Wu *et al.*, 1998).

From the viewpoint of disease prevention, this study will be most useful as a situation in drawing up an appropriate hearing conservation program in the factory. The noise mapping has provided adequate information on the source and intensity of noise. The audiometric examinations have identified workers with some degree of hearing impairment whose hearing ability should be guarded from further insult. Likewise, these results have also identified workers whose auditory faculties may be prevented from deteriorating because of the hazard in the workplace.

The greatest number of occupational and community noise studies have focused on the possibility that noise may be a risk factor for cardiovascular disease. Many studies in occupational settings have indicated that workers exposed to high levels of industrial noise for 5-30 years have increased blood pressure and statistically significant increases in risk for hypertension, compared to workers in controlled areas (WHO, 1999).

In this study, the behaviors of the arterial blood pressure (systolic and diastolic) and pulse rate for studied workers as dependent variables showed a positive increase with the occupational noise levels (Figs. 3.12 - 3.14), age (Figs. 3.15 - 3.19), and duration of employment (Figs. 3.20 - 3.24) as independent variables. The findings of this study support the hypothesis that exposure to high industrial noise levels may be a risk factor for cardiovascular disease via increased systolic and diastolic blood pressure, and pulse rate (Melamed & Ribak, 1997; Regecova & Kellerova, 1995; WHO, 1999).

According to the survey that was done to compare blood pressure in deaf-mute children and children with normal hearing, it was suggested that noise exposure is associated with higher systolic and diastolic blood pressure (Wu *et al.*, 1998). Green et al. (1991) suggested that industrial noise exposure is associated with higher ambulatory blood pressure and heart rates in men under 45 years old.

The changes in the diameter of blood vessels in response to noise pollution will increase the systolic and diastolic blood pressure. In general, high noise pollution level seems to increase the stress reaction that elevates blood pressure. This process will increase cardiac oxygen demand and causes an increase in the pulse rate, a diagrammatic presentation of these concepts is shown as follows (Harris, 1979):

Noise → stress reaction → affect blood pressure → damage arterial wall → increase cardiac oxygen demand → elevated heart rate → heart attack (Harris, 1979).

In this study, pulse rate (P.R), systolic and diastolic blood pressure (SBP & DBP) correlated positively with the occupational noise levels in most studied industrial plants (Table 3.7). This finding conforms to the results of other reports of noise-induced blood pressure elevation and a higher incidence of hypertension which were detected in field studies in subjects who exposed to high levels of noise (Green *et al.*, 1991; Melamed & Ribak, 1997; Regecova & Kellerova, 1995; Wu *et al.*, 1998). In addition, this work also showed that there are significant shifts in mean-values of these variables shortly before exposure to occupational noise (pre-exposure) and during exposure of at least 4 hours after work onset. Table 4.1 showed amount of shifting in mean-values of pulse rate (P.R), systolic blood pressure (SBP), and diastolic blood pressure (DBP), before and during exposure to occupational noise.

Table 4.1. Amount of shifting in mean-values of pulse rate (P.R), systolic (SBP) and diastolic blood Pressure (DBP) in the whole study population.

Name of industrial plants	Amount of mean-values shifting of P.R (in beats/min)	Amount of mean-values shifting of SBP (in mmHg)	Amount of mean-values shifting of DBP (in mmHg)
Vegetable Oils	3.62 higher	8.85 higher	7.38 higher
Arabic Paints	2.3 higher	5.47 higher	1.47 higher
Al - Carton	4.7 higher	1.23 higher	1.67 lower
Al - Aqad	6.59 higher	1.72 higher	0.3 higher
Al - Andalus	2.93 higher	2.67 higher	3.73 higher
Al - Nasir	6.38 higher	1.75 higher	0.7 lower
Al - Arz	4.86 higher	1.89 higher	1.39 higher
Cans Factory	7.31 higher	4.07 higher	0.19 higher

Environmental noise is not believed to be a direct cause of mental illness, but it is assumed that it accelerates and intensifies the development of latent mental disorder. Studies on the adverse effects of environmental noise on mental health cover a variety of symptoms, including anxiety, emotional stress, nervous complaints, nausea, headaches, instability, argumentativeness, sexual impotency, change in mood, increase in social conflicts, as well as general psychiatric disorders such as neurosis, psychosis, and hysteria (WHO, 1999).

Based on the results of demographic and health status questionnaire, which was distributed on all studied workers. There is an association between exposure to high level of occupational noise pollution in long-term duration and feeling of nervous tension, low concentration, nausea, dizziness, migraine headache, hearing impairment, and muscle contraction, which are related to mental and physiological health effects.

Considerable differences were found between the frequency and percentage of feeling of mental [nervous tension, sleep disturbance] and physiological [hearing impairment] disease cases before and after receiving the current job. These results prove that there is a significant correlation between these disease cases and receiving work with high noise emission level. There is a relationship between work accidents and exposure to high levels of occupational noise as a source of annoyance, stress, and dissatisfaction.

Three conclusions can be drawn from this study about the effects of long-term exposure to high levels of occupational noise in industrial plants: (a) significant interactions were found between several degrees of hearing impairment and levels of occupational noise exposure, (b) exposure to high levels of occupational noise could be a risk factor for cardiovascular disease via increased systolic and diastolic blood pressure, and pulse rate, and (c) significant associations were found between exposure to occupational noise and feeling of mental disorders [such as: nervous tension, and sleep disturbance].

This study aimed to provide reliable and useful data for planners and decision-makers to improve the status of occupational environment. However, additional researches are needed to support this study and to clarify the risks associated with occupational noise and its health effects.

A major step forward in raising the awareness of both the public and of decision-makers is the recommendation to concentrate more research and development on variables, which have monetary consequences (NIOSH, 1998).

The potential health effects of environmental noise include hearing impairment, startle and defense reactions, aural pain, ear discomfort, speech interference, sleep disturbance, cardiovascular effects, performance reduction, and annoyance responses. These health effects, in turn, can lead to social handicap, reduced productivity, decreased performance in learning, absenteeism in the workplace and school, increased drug use, and accidents (WHO, 1999).

The following recommendations were considered appropriate (NIOSH, 1998; WHO, 1999):

A. Authorities should consider the protection of populations from environmental noise as an integral part of their policy for environmental protection.

B. Authorities should consider implementing action plans with short-term, medium-term, and long-term objectives for reducing noise levels.

C. Authorities should include noise as an important issue, when assessing public health matters and support more research related to the health effects of noise exposure.

D. Legislation should be enacted to reduce sound pressure levels, and existing legislation should be enforced.

E. Authorities should develop low-noise implementation plans.

F. Cost-effectiveness and cost-benefit analyses should be considered as potential instruments, when making management decisions.

G. Authorities should support more policy-relevant research into noise pollution.

The subject of noise control involves knowledge of sound propagation, acoustical insulation, and sound absorption as well as knowledge of vibration control. Noise exposure control can be accomplished by one or more of the following courses of action: (a) reduction of noise at the source, (b) interruption of the transmission path between source and receiver, and (c) protection of the receiver (Purdom, 1980).

In this study, most selected industrial plants have higher noise levels than the established limits for occupational noise exposure. Continuous exposure of the workers to such high noise levels can affect hearing, cardiovascular systems, and mental health (NIOSH, 1998).

There are several methods, which can be applied to reduce the current problems of occupational noise pollution to acceptable levels. These may be short-term and long-term, some of them are administrative while others are technical.

Many recommendations may be used to mitigate the occupational noise pollution levels and their hazardous impacts on human health. In summary the following actions are recommended:

- Shifting noisy sources away from residential areas.
- Suppression of the occupational noise at the source by shielding the sources of noise generation [i.e., machines in this study]. Sound absorption, sound insulation, and vibration control play an important role in reducing the general noise level and minimizing excessive background noise.
- Allowing enough spaces between machines.
- Providing regular maintenance for all noise producing equipment.
- Consider the noise consequences when designing factories' buildings.
- Workers should be provided with noise protective equipment, such as earplugs.
- Pre-employment audiologic evaluation should be done to establish an audiometric baseline for each worker.

- Periodic audiologic evaluations should be done for exposed people to detect minimal hearing impairment early.
- Limiting the time spent in noisy environment [reducing the exposure time of the workers].
- Legislation should be enacted to reduce sound pressure levels.
- Responsible authorities should organize workshops on how to mitigate occupational noise and its impacts.

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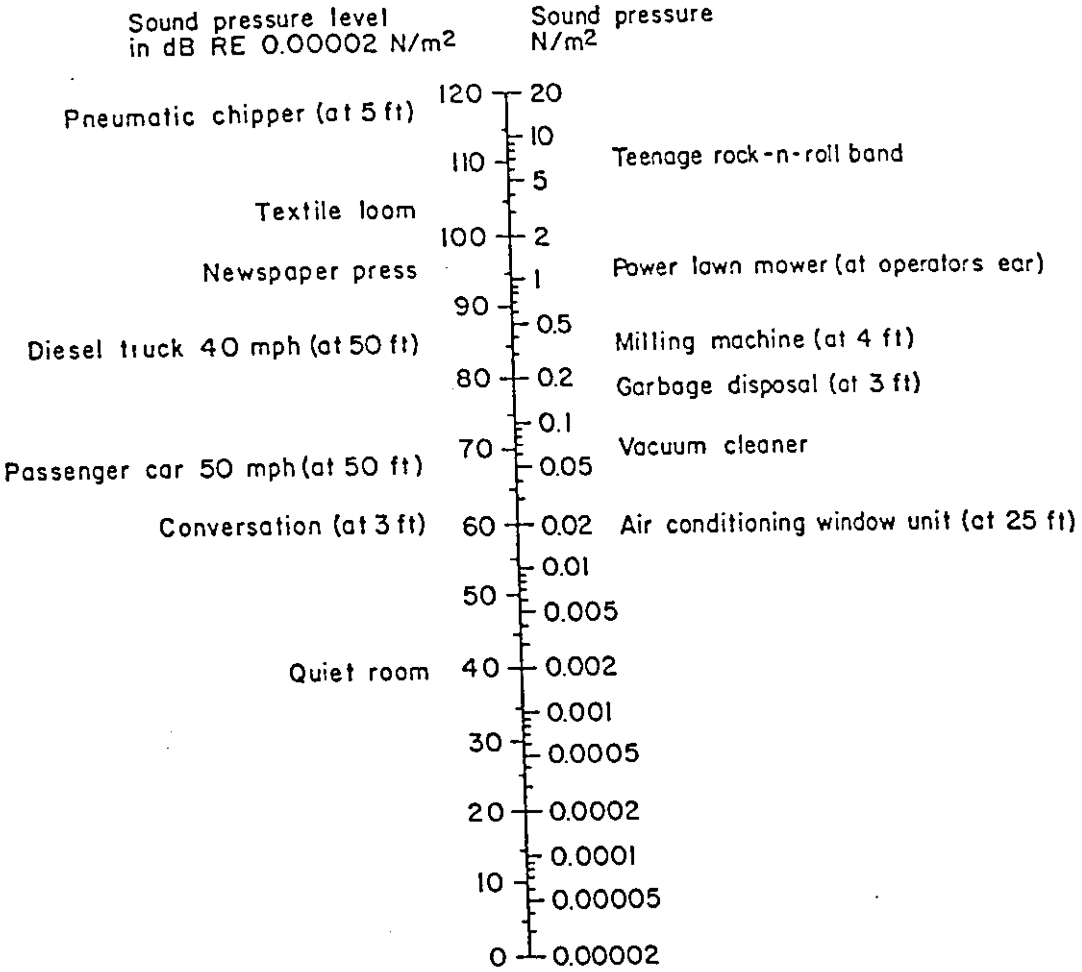
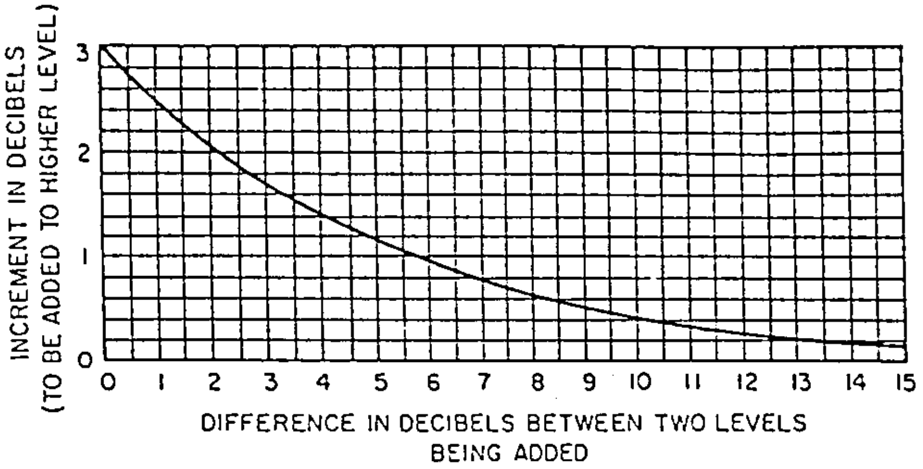
APPENDIX A

Fig. A.1. Relationship between A-weighted sound pressure in decibels (dB) and sound pressure in N/m².



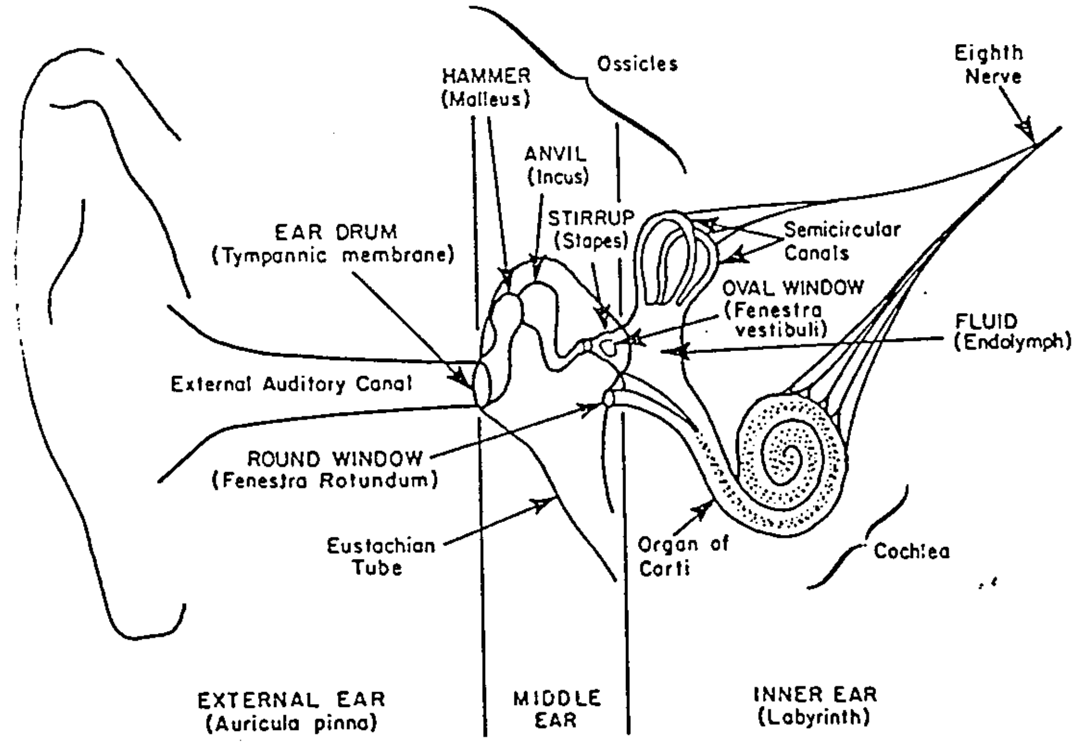
Note: From *Environmental Health* [2nd ed.] (p. 498), by P. W. Purdom (1980). New York: Academic Press, INC.

Fig. A.2. Chart for combining sound pressure levels (SPL) emission from more than one source.



Note: From *Environmental Health* [2nd ed.] (p. 498), by P. W. Purdom (1980). New York: Academic Press, INC.

Fig. A.3. Anatomy of human ear.



Note: From *Environmental Health* [2nd ed.] (p. 498), by P. W. Purdom (1980). New York: Academic Press, INC.

Table A.4. Guideline values for community noise in specific environments.

Specific Environment	Critical Health Effect(s)	L_{Aeq} dB(A)	Time base (hours)	L_{Amax} fast (dB)
Outdoor living area	Serious annoyance, daytime and evening	55	16	-
	Moderate annoyance, daytime and evening	50	16	-
Dwelling, indoors	Speech intelligibility &moderat annoyance daytime & evening	35	16	-
Inside bedrooms	Sleep disturbance, nighttime	30	8	-
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	-
School classrooms & pre-schools, indoors	Speech intelligibility, disturbance of information, extraction, message communication	35	During class	-
Pre-school, bedrooms, indoor	Sleep disturbance	30	Sleeping time	45
School, playground, outdoor	Annoyance (external source)	55	During time	-
Hospital, ward	Sleep disturbance night-time	30	8	40
Rooms, indoors	Sleep disturbance, daytime and evening	30	16	-
Hospitals, treatment rooms, indoors	Interference with rest and recovery	*	-	-

Table A.4/ Cont.

Industrial, and commercial, indoors and outdoors	Hearing impairment	70	24	110
Ceremonies, festivals and entertainment events	Hearing impairment (patrons: <5 times /year)	100	4	110
Public addresses, indoor and outdoors	Hearing impairment	85	1	110
Music and other sounds through headphones/ earphones	Hearing impairment (free-field value)	85 **	1	110
Impulse sound from toys, fireworks and firearms	Hearing impairment (adults)	–		140 #
	Hearing impairment (children)	–		120 #
Outdoors in parkland and conservation areas	Disruption of tranquility	# #		

Note: from *Guidelines for community noise* (p. 15), by WHO (1999). London.

* As low as possible, ** under headphones, adapted to free – field values, # peak sound pressure measured 100mm from the ear, # # existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low.

Table A.5. OSHA's table of permissible exposure limit (PEL) for noise.

Time exposure Permitted (hr)	A-Weighted sound level dB (A)	Time exposure Permitted (hr)	A-Weighted sound level dB (A)
32	80	1.3	104
27.9	81	1.0	105
24.3	82	0.87	106
21.1	83	0.76	107
18.4	84	0.66	108
16.0	85	0.57	109
13.9	86	0.50	110
12.1	87	0.44	111
10.6	88	0.38	112
9.2	89	0.33	113
8.0	90	0.29	114
7.0	91	0.25	115
6.2	92	0.22	116
5.3	93	0.19	117
4.6	94	0.16	118
4.0	95	0.14	119
3.5	96	0.125	120
3.0	97	0.110	121
2.6	98	0.095	122
2.3	99	0.082	123
2.0	100	0.072	124
1.7	101	0.063	125
1.5	102	0.054	126
1.4	103	0.047	127

Note: from Code of Federal Regulation 29 CFR. Environmental control and noise.

Table A.6. Maximum permissible sound level (emission limits) Used in Austria.

Category	Area and locations	Maximum permissible equivalent sound level, (L_{Aeq}) day	night
	A) Building Lands:		
1	Quiet area, spa area, and hospital	45	35
2	Residential area in suburbs, weekend, residential area, rural housing area, schools	50	40
3	Urban residential area, area for agricultural and forestry enterprises with flats	55	45
4	City (offices, shops, commerce, administration without noise emission, flats), area for enterprise without noise emission	60	50
5	Area for enterprises with little noise emission (distribution, services, administration)	65	55
	B) Grass Land		
1	Recreation area, spa area	45	35
2	Parks ,cemeteries	50	40
3	Games and sport fields without noise emission, market gardens, and allotment	55	45
4	Games and sport without slight noise emission	60	50
5	Smaller games and sports installations with spectator stand	65	55
6	Large games and sports installations with spectator stand	70	60

Note: From *Selected Presentations: Informal Regional Consultation Meeting on Noise Pollution* (p. 52), by WHO (1995). Eastern Mediterranean Regional Office, Regional Center for Environmental Health Activities (CEHA), Amman, Jordan.

Table A.7. Noise threshold limit values as permissible by American National Standard Specifications for Sound Level Meter (SLM).

Sound levels, dB(A)	Permissible duration of exposure (hours/day)
80	16
85	8
90	4
95	2
100	1
105	1 / 2
110	1 / 4
115	1 / 8

Note: From *A Textbook of Environmental Chemistry and Pollution Control* (p. 146), by S. S., Dara (1997). Ram Nagar, New Delhi: S. Chand & Company LTD.

Table A.8. Comparison of various standards for safe noise exposure.

	EPA		ANSI and NIOSH			OSHA	
dB(A)	hours	minutes	hours	minutes	seconds	hours	minutes
70	24						
73	12						
76	6						
79	3						
82	1	30					
85		45	8	0			
88		23	4	0			
90						8	
91		11	2	0			
92						6	
94		6	1	0			
95						4	
97		3		30	0	3	
100				15	0	2	
102						1	30
103				7	30		
105						1	
106				3	45		
109				1	53		
110							30
112					56		
115					28		25

Note: From *Criteria for a Recommended Standard, Occupational Noise Exposure*, by NIOSH (1998). Cincinnati, Ohio.

Table A.9. Maximum permissible occupational noise exposure duration per week allowed under the limits of 90, 85 dB(A) and proposed limit of 88 dB(A) with halving rate of 3 dB(A).

Noise level dB(A) (L_{eq})	Occupational noise exposure duration / week								
	90 dB(A)			85 dB(A)			88 dB(A)		
	hr	min	sec	hr	min	sec	hr	min	sec
85				40	00	00			
86				30	00	00			
87				25	00	00			
88				20	00	00	48	00	00
89				15	00	00	36	00	00
90	40	00	00	12	30	00	30	00	00
91	30	00	00	10	00	00	24	00	00
92	25	00	00	7	30	00	18	00	00
93	20	00	00	6	15	00	15	00	00
94	15	00	00	5	00	00	12	00	00
95	12	30	00	3	45	00	9	00	00
96	10	00	00	3	07	30	7	30	00
97	7	30	00	2	30	00	6	00	00
98	6	15	00	1	52	30	4	30	00
99	5	00	00	1	33	45	3	45	00
100	3	45	00	1	15	00	3	00	00
101	3	07	30	0	56	15	2	15	00
102	2	30	00	0	46	53	1	52	30
103	1	52	30	0	37	30	1	30	00
104	1	33	45	0	28	08	1	07	30
105	1	15	00	0	23	26	0	56	15
106	0	56	15	0	18	45	0	45	00
107	0	46	53	0	14	04	0	33	45
108	0	37	30	0	11	43	0	28	08
109	0	28	08	0	09	23	0	22	30
110	0	23	27	0	07	02	0	16	53
111	0	18	45	0	05	52	0	14	04
112	0	14	04	0	04	42	0	11	15
113	0	11	43	0	03	31	0	08	26
114	0	9	23	0	02	56	0	07	02
115	0	7	02	0	02	21	0	05	38

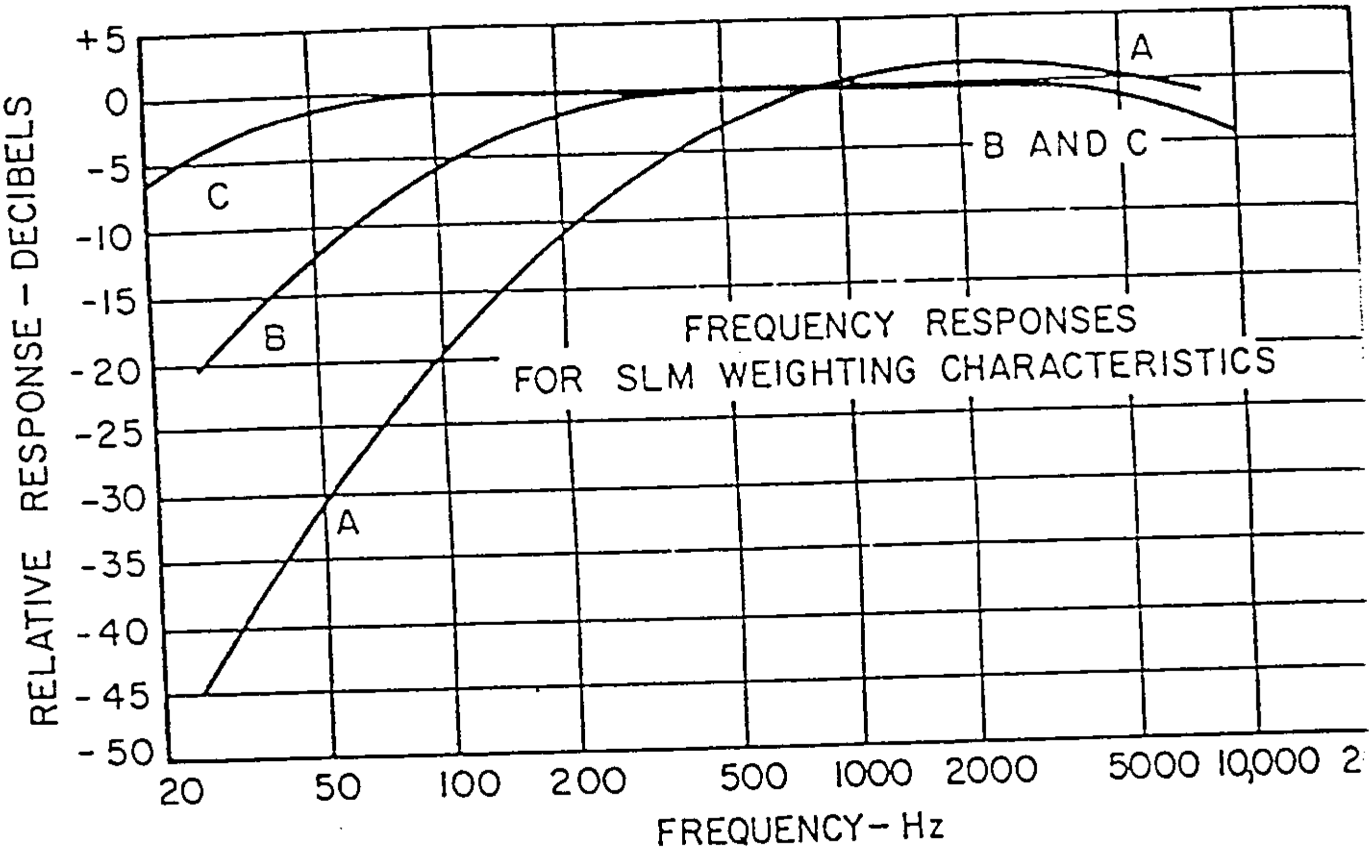
Note: From Occupational Noise Exposure Limits for Developing Countries (p. 91), by G. H., Shaikh (1999). *Applied Acoustics, 57*, 89 – 92.

APPENDIX B

Table B.1. Environmental status of the studied industrial plants.

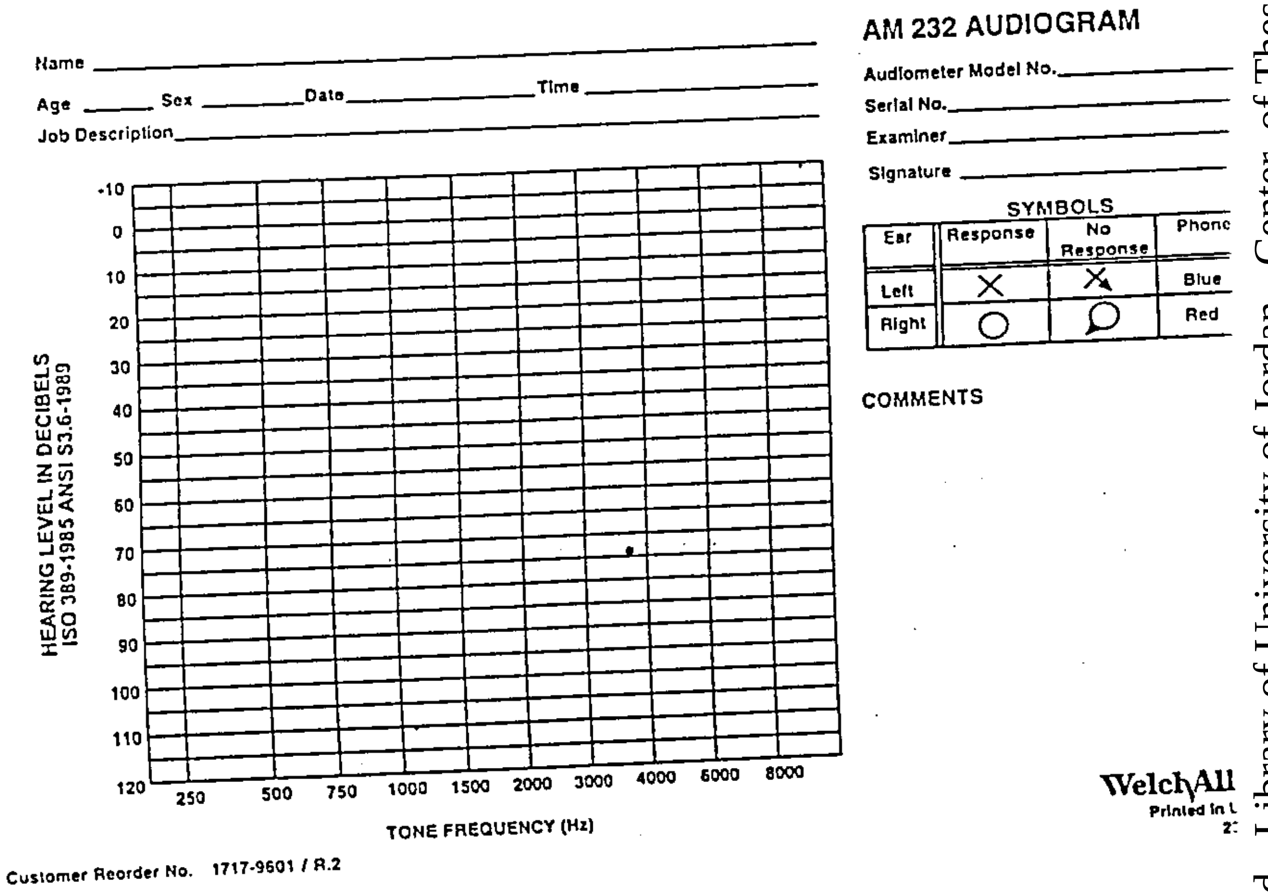
Name of industrial plants	Location of industrial plants	Area in m^2	Machines	Nature of building material	Surrounding area: Trees, walls, yards, parking, and other installations
Vegetable Oils	Industrial + Commercial	1000	4 machines (2-25 yr. under working), 4 m far from each other	Concrete and metal	Surrounding with some trees, 3 m high wall, yards (40 m width), parking , main street, and other factories
Arabic Paints	Industrial + Commercial	500	7 machines (2-12 yr. under working), 6 m far from each other	Concrete, blocks, and metal	Surrounding with 4 m high wall, yards (10 m width), parking, branch street, and other factories
Al - Carton	Industrial	1200	16 machines (4-20 yr. under working), 4 m far from each other	Concrete, blocks, and metal	Surrounding with some trees, 2 m high wall, yards (5 m width), parking, branch street, and other factories
Al - Aqad	Industrial	800	120 machines (1-10 yr. under working), 2 m far from each other	Concrete and blocks	Surrounding with some trees, 4 m high wall, yards (8 m width), parking, and other factories
Al - Andalus	Industrial	600	8 machines, (4-8 yr. under working), 5 m far from each other	Concrete and blocks	Surrounding with 3 m high wall, yards (3 m width), branch street, and other factories
Al - Nasir	Industrial	1500	16 machines (4-20 yr. under working), 4 m far from each other	Concrete and blocks	Surrounding with 4 m high wall, yards (3 m width), branch street, and other factories
Al - Arz	Residential + Commercial	800	8 machines (2-20 yr. under working), 4 m far from each other	Concrete and blocks	Surrounding with main street, residential, and commercial zones
Cans Factory	Industrial	1000	6 machines (4-12 yr. under working), 8 m far from each other	Concrete and metal	Surrounding with 3 m high wall, yards (5 m width), parking, main street, and other factories

Fig. B.2. Frequency response of A, B, and C – weighted networks.



<u>Note</u>: From *Environmental Health* [2nd ed.] (p. 498), by P. W. Purdom (1980). New York: Academic Press, INC.

Fig. B.3. Audiogram form uses to record hearing threshold levels (HTL) in dB (A) according to different frequencies in Hz.



AM 232 AUDIOGRAM

Name ______________________________

Age ______ Sex ________ Date ______________ Time ______________

Job Description ______________________________

Audiometer Model No. ______________

Serial No. ______________

Examiner ______________

Signature ______________

SYMBOLS

Ear	Response	No Response	Phone
Left	✕	✕↘	Blue
Right	○	○↙	Red

COMMENTS

Customer Reorder No. 1717-9601 / R.2

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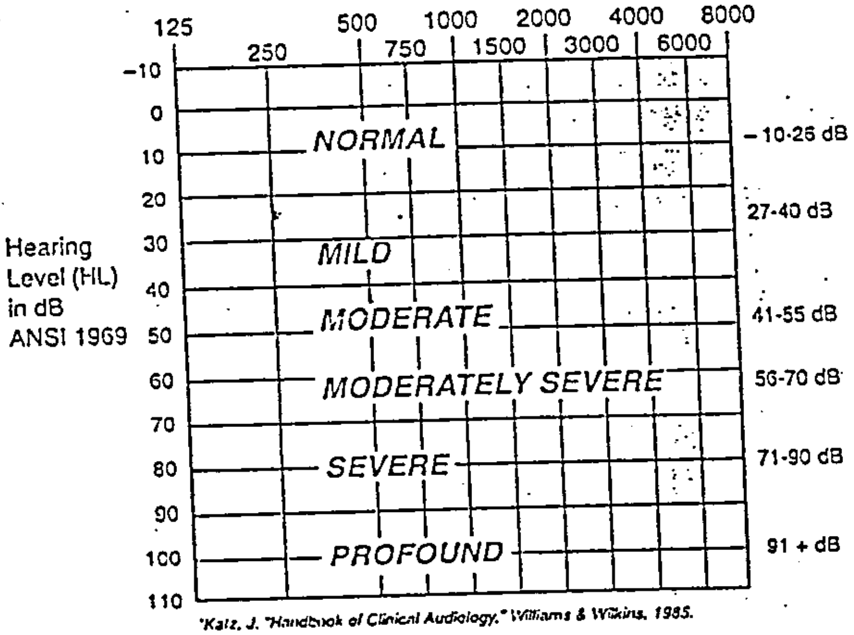
Printed in

Fig. B.4. Scale of the degrees of hearing impairment at different frequencies [according to ANSI (1969) and Katz (1985)].

Threshold Audiometry

Audiogram Showing
*Scale of Hearing Impairment**
Frequency in Hz



*Katz, J. "Handbook of Clinical Audiology." Williams & Wilkins, 1985.

Threshold Audiometry

Welch Allyn®

Appendix B.5. Questionnaire of the environmental status of studied industrial plants.

(إستبانة المصنع)

رقم الاستبانة: (   ).   اليوم والتاريخ:

اسم المصنع: طبيعة الصناعة:

تاريخ البدء بالعمل في المصنع:

عدد العمال: ذكور: إناث:

فئاتهم العمرية:

24-15: (   )   34-25 : (   )

44-35: (   )   54-45 : (   )

أعلى من ذلك:

عدد سنوات الخدمة المتواصلة في المصنع:

2-0 : (   )   4-2 : (   )

6-4 : (   )   8-6 : (   )

10-8: (   )   أكثر من 10: (   )

عدد خطوط الإنتاج :

المكنات :

عددها :

تواريخ صنعها :

عدد سنوات خدمتها في المصنع:

بعدها عن بعضها البعض :

معلومات أخرى :

مساحة بناء المصنع: طبيعة البناء:

مادة بناء الجدران :   مادة بناء السقف:

موقع المصنع :

المنشآت القريبة من المصنع :

شارع رئيسي: شارع فرعي:

مناطق سكنية: أسواق تجارية:

مصانع أخرى :   منشآت أخرى :

هل هناك (أشجار، أسوار، ساحات، كراجات للسيارات) تحيط بالمصنع؟:

أشجار: أسوار:

ساحات: كراجات:

Appendix B.6. Questionnaire of the demographic and health status of studied workers.

(استبانة العامل)

استبانة رقم : (   )
الجنس : ....
مكان العمل : ....

اليوم والتاريخ : ....
العمر : ....
طبيعة العمل : ....

عدد ساعات العمل اليومية : ....
عدد سنوات الخبرة المتواصلة : ....
هل تشعر أثناء ساعات العمل بالاعراض التالية؟ :

الاعراض	درجة الاعراض			
	لا أشعر	خفيف	شديد نوعا ما	شديد جدا
التوتر العصبى				
عدم التركيز				
الغثيان				
الدوار				
الصداع النصفي				
الضعف في السمع				
الارهاق العضلي العام				

الحالات المرضية قبل وبعد استلام العمل الحالي :

الحالات المرضية	قبل استلام العمل الحالي			بعد استلام العمل الحالي	
	نعم		لا	نعم	لا
امراض القلب والشرايين					
لمراض ضغط الدم					
ضعف السمع					
التوتر العصبى					
أضطراب في النوم					
امراض اخرى					

هل سبق وأن تعرضت لحوادث عمل؟ 1. نعم. 2. لا.
إن كانت الاجابة (بنعم)، فكم عددها؟ وما طبيعتها؟

Analysis	Pre-exposure	Post- exposure
Blood Pressure		
Heart Pulse		

تأثير الضجيج الصناعي على معدلات ضغط الدم (الانقباضي والانبساطي)، ونبض القلب، ودرجة السمع عند عمال المصانع في مدينة نابلس

ناظم سعد عبد الرحيم حنيني

إشراف

بروفيسور د. محمد سليم اشتيه و د. عصام راشد عبد الرازق

تمت دراسة أثر التعرض للضجيج الصناعي على معدلات ضغط الدم (الانقباضي والانبساطي)، ونبض القلب، ودرجة السمع عند مجموعة من العمال في ثماني وحدات صناعية في مدينة نابلس. تتوزع الوحدات الصناعية المدروسة على عدة قطاعات صناعية منها: الكيميائية، والبلاستيكية، والغذائية، والورقية، والمعدنية، وصناعة الملابس (ماكنات خياطة). تقع هذه الوحدات في مواقع متنوعة من حيث استخدامات الأرض فمنها: السكنية، والتجارية، والصناعية. لم يراعى عند تصميم وبناء أي من هذه الوحدات المعايير البيئية العالمية الخاصة بتخفيف الآثار المترتبة على انبعاث الضجيج من الأنشطة الصناعية المختلفة، كما لم تستخدم أي من الوسائل الخاصة بالحد من آثاره السلبية على صحة العاملين.

ضم مجتمع الدراسة 208 من العمال الذكور ممن تنطبق عليهم شروط الدراسة [تتراوح أعمارهم بين 25 – 45 سنة، مدة مكوثهم في العمل الحالي سنتين على الأقل، لم يعانوا مسبقا من اعتلالات في السمع أو القلب أو الدورة الدموية]، أخضعوا جميعا لعدة فحوصات أستخدم بها جهاز خاص بتحديد درجة السمع [Audiometer] بعد تعريض أذني كل عامل إلى مجموعة من الترددات، وجهاز قياس ضغط الدم ومعدل نبضات القلب [Wrist Blood Pressure Monitor]. أجريت هذه الفحوصات مرتين في اليوم، الاولى قبل البدء بالعمل الصباحي بقليل، والثانية بعد أربع ساعات على الأقل من بدء العمل.كما أستخدم جهاز خاص بتسجيل مستويات الضجيج [Sound Level Meter (SLM)] بعد وضعه في مواقع مركزية داخل كل وحدة صناعية لمدة تتراوح بين 4 – 6 ساعات أثناء العمل الصباحي.

بلغ معدل أعمار العمال الذين تم اختيارهم (34.85 ± 2.43 yr.)، ومعدل سنوات خدمتهم في العمل الحالي (8.55 ± 2.71 yr.)، كما بلغ معدل ساعات العمل اليومية في جميع الوحدات الصناعية (11.25 ± 1.04 hr/day)، بمعدل (10 hr/day) في 37.5 % من الوحدات المدروسة، و (12 hr/day) في 62.5 % منها.

تراوحت مستويات الضجيج في الوحدات الصناعية [77.4 - 92.4 dB(A)] بمعدل [84.43 ± 4.34 dB(A)]. أظهرت هذه القراءات أن العمال في معظم الوحدات الصناعية المدروسة يتعرضون يوميا لمستويات من الضجيج الصناعي تفوق المعايير الموصى بها عالميا.

أظهرت الدراسة أن هناك علاقة ارتباط قوية [$p < 0.05$ and $p < 0.01$] بين ضغط الدم (الانقباضي والانبساطي)، ونبض القلب، ودرجة السمع على ترددات مختلفة، ومستويات الضجيج الصناعي. كما دلت النتائج على وجود علاقة طردية بين معدلات ضغط الدم (الانقباضي والانبساطي)، ونبض القلب، ودرجة السمع على ترددات مختلفة، وبين أعمار العمال وعدد سنوات خدمتهم المتواصلة في المصنع.

أظهرت نتائج القراءات المأخوذة قبل وبعد التعرض للضجيج زيادة ملحوظة في معدلات ضغط الدم (الانقباضي والانبساطي)، ونبض القلب، ودرجة السمع على ترددات مختلفة بعد التعرض للضجيج عنها قبل التعرض له.

اعتمادا على التعريفات العالمية المختلفة لمستوى الإعتلالات السمعية الناجمة عن التعرض للضجيج الصناعي [ANSI, EPA, NIOSH, and OSHA's definition of Hearing Impairment] تبين أن هناك علاقة طردية بين نسب الإصابة بالإعتلالات السمعية ومستويات الضجيج الصناعي مع عدم إهمال أثر العوامل الأخرى كأعمار العاملين وعدد سنوات خدمتهم.

تبين من نتائج الإستبانة التي رصدت أثر التعرض لمستويات عالية من الضجيج الصناعي على الصحة العصبية والجسدية للعاملين شعور بعضهم باضطراب في النوم، الصداع النصفي، الدوار، الغثيان، التوتر العصبي، وعدم التركيز المرتبط بزيادة حوادث العمل. بناءاً على ما تقدم من نتائج فقد خلصت الرسالة بجملة من التوصيات الخاصة بضرورة استخدام الوسائل الكفيلة للتخفيف من انبعاثات الضجيج الصناعي والحد من آثاره السلبية على صحة العاملين.