An-Najah National University
Faculty of Graduate Studies

Health Effects of Occupational Noise Exposure in the Range (90 - 110) dB(A) Especially on Blood Oxygen Saturation of Workers in Selected Industrial Plants

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This Thesis is Submitted in Partial Fulfillment of Requirements for the Degree of Master of Physical Sciences, Faculty of Graduate Studies, An-Najah National University- Nablus, Palestine

2012

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Dedication

To the angels disguised in human appearance to guide us through our way…to the candle that burned itself yesterday to light our life today…to our supportive parents, whose encouragement is constantly rushing to nurture our souls, to the one whose eyes shine with hope and his smiles with love, to the one who shares my life…to my fiancé, to all my family with respect and love.

Acknowledgments

I am very grateful to my respectable supervisors Prof. Dr Issam Rashed Abdel-Raziq and Dr. Zeid Naim Qamhieh, for their helpful efforts, fruitful guidance and continual encouragement throughout entire research. Special thanks are addressed to the plant’s managers, owners, and workers for their help and cooperation to make this research possible.

الاقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

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اقر بأن ما اشتملت عليه هذه الرسالة، إنما هي نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وأن هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيل أي درجة علمية أو بحث علمي لدى أي مؤسسة تعليمية او بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's name: **اسم الطالب:**

Signature: **التوقيع :**

Date: **التاريخ:**

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List of Abbreviations

ANOVA	Analysis of Variance
ASHA	American Social Health Association
dB	Decibel (s)
dB(A)	Decibel (s) by a Weighting Filter (A)
DBP	Diastolic blood pressure
EPA	Environmental Protection Agency
F_1	Metal (Haddad) Factory
F_2	Chemical (ALbareeq) Factory
F_3	Concrete Factory
F_4	Food Factory
F_5	Sewing (Clothes) Factory
F_6	Stonecutter Factory
F_7	Carpentry
HTL	hearing threshold levels
ICU	Intensive care unit
L_{10}	Noise Level Exceed 10% of Time
L_{90}	Noise Level Exceed 90% oF Time
LED	Light Emitting Diod (s)
L_{eq}	Equivalent Noise Level
L_{NP}	Noise Pollution Level

Log	Logarithmic Scale
Max	Maximum
Min	Minimum
NIHL	Noise-induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
p	Measured Sound Pressure
$\mathbf{P_{ref}}$	Reference Sound Pressure of Audible Sound
P.R	Pulse Rate
RMS	Root Mean Square
SBP	Systolic Blood Pressure
S.D	Standard Deviation
sec	Section (s)
SPL	Sound Pressure Level
$\mathbf{SPO_2\%}$	Blood Oxygen Saturation
WHO	World Health Organization

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Abstract

This study shed the light on the effects of occupational noise level on some of the dependent variables, such as: blood oxygen saturation (SPO_2%), pulse rate (P.R), arterial blood pressure (systolic (SBP) and diastolic (DBP)), and hearing threshold levels (HTL). 115 workers of both genders (96 male, 19 female), with mean age 35.22 yr, and the mean duration of employment 6.99 yr, were randomly chosen as a sample to fulfill the aim meant.

This sample was taken from seven industrial plants of various types in Jenin city. The values of sound pressure levels (SPL) in all studied plants ranged from 82.5 dB(A) to 110.5 dB(A), with mean of (94.34 dB(A)). A number of measurements concerning with blood oxygen saturation, Pulse rate, arterial blood pressure (systolic and diastolic), and hearing threshold levels at different frequencies were taken for the selected sample before and after 6 hours exposure to noise. Strong positive correlation (Pearson Correlation Coefficient) with SPL was found for all measured variables.

The statistical results for the dependent variables (SPO_2%, P.R, SBP, DBP, HTL) showed that Pearson correlation coefficient (R) between sound pressure level and the dependent variables are approximately equal to one, and the Probabilities (P) are < 0.05. For example, blood oxygen saturation has Pearson's Coefficient R = 0.779 and probability P = 0.039, whereas pulse rate has R= 0.790 and P= 0.035, while systolic blood pressure has R= 0.734 and P= 0.030, in addition diastolic blood pressure has R= 0.795 and P= 0.033, and the values of R for HTL at different frequencies ranged from 0.626 to 0.954.

This study showed that the health effects of noise depend on the noise level itself, more specifically, workers exposed to noise more than 90 dB(A) have a significant shift of the mean measured values (blood oxygen saturation, pulse rate, arterial blood pressure (systolic and diastolic), and hearing threshold levels), more than workers exposed to noise less than 90 dB(A).

Chapter one

Introduction

1.1Background

People throughout the world are facing many unpleasant pollution effects such as air pollution, water pollution and noise pollution which are seriously influencing human's life**.**

The term noise is commonly used to describe sounds that are disagreeable or unpleasant produced by acoustic waves of random intensities and frequencies (Akhtar H. N., 1996). Some authors define noise as any audible acoustic energy that adversely affects the physiological or psychological well being of the people (Hashmi S.F., 2009). However, noise is measured using a logarithmic decibel (dB) and can be described by the help of loudness (intensity) and pitch (frequency).

Because of the rapid growth in technology that has mainly occurred in urban countries not only in the developed one, but also in the developing countries as well, noise pollution has become one of the major threats that face the environment and the cost of reducing it in future years is expected to be insurmountable (Joshi S., 2003).

Noise pollution stems from a variety of sources such as traffic, aircrafts, rock bands, amplified music, television, garbage trucks and noise from alarms and watercrafts. Moreover, as for residents settling down in industrial areas or near to the airports, they are more affected by noise because of loud sounds from factories and airplanes.

Noise pollution is not only an environmental problem, but also a serious health risk. The World Health Organization (WHO) has established maximum allowable levels of noise, above which people are harmed. Proportion of people exposed to noise is greatly increasing; this has direct and indirect effects on people and can lead to the health hazards. Some of the major health hazards caused by noise are: decrease in blood oxygen saturation, permanent hearing loss, high blood pressure, muscle tension, headaches, higher cholesterol levels, irritability insomnia, and psychological disorder (Miller G. T., 1998).

The overall loudness of environmental noise is doubling every ten years, so that immediate and serious attention must be given to control this growing problem (Chedd G., 1981). Hence scientists attempt to discuss and study the effects of noise pollution on human's health.

1.2 Literature Review

Noise is increasingly being recognized as a physical factor that has negative health effects. The most involved and therefore has received the most attention is the cardiovascular system. However few specific studies have been performed concerning the relationship between noise and myocardial disease.

It was shown that noise can produce physiological changes. For example, studies in the intensive care unit (ICU) (Short M., 2011) agree that patients exposed to noise pollution have decreased blood oxygen saturation (increasing need for oxygen support therapy). A study carried out by Zahr and Balian on 55 preterm infants between 23 and 37 weeks, exposing them to common ICU environmental noises such as alarms, phones and loud conversations, it was found that the average blood oxygen saturations were significantly lower during noisy periods (Zahr L.K., 1995). Other study (Long J.G., 1980) looked at two preterm infants between 34 and 35 weeks, exposing them to sudden ICU environmental noises at 70–75 dB(A), all of the environmental stimuli were associated with an increase in respiratory rate, as well as a decrease in blood oxygen saturation.

In a study conducted at Peshawar (Mahmood R., 2007), it was noted that there was a significant rise in blood pressure in response to noise. The average rise in systolic blood pressure was 2.462 mm Hg while it was 3.064 mm Hg for diastolic blood pressure. The blood pressure came to resting value within two minutes after stopping exposure to noise in more than 50% of the subjects. Another study were done in China (Chan C., 2007), measured the arterial vascular properties of autoworkers during work and sleep periods. The workers with eight hour average noise exposure of 85 dB(A) had lower arterial elasticity and higher blood pressure than workers with workplace average noise exposure of 59 dB(A). A study conducted in Aligarh (Hashmi S.F., 2009) on 114 subjects of both genders from various lock factories indicates that industrial noise could be possible contributing factor in the development of arterial hypertension as systolic blood pressure increased in 63.15%, diastolic blood pressure increased in 57.02%, while the heart rate increased in 17.54% of all workers.

Cardiovascular effects of noise pollution are not unique to adults. Unfortunately, there is evidence that young children are also at risk. In one study performed in 1995, blood pressure and heart rate was measured in 1,542 children between the ages of 3-7 years old who belonged to areas with noise was greater than 60 dB(A). The results showed that the preschool children had a higher mean systolic and diastolic blood pressure than those children in quite areas (Regecova V., 1995).

A prospective study was conducted at Khyber Medical College, Peshawar, to see the effect of short term noise (10 minutes) on heart rate and it was found the heart rate increase in male (93.44%) and female (83.93%) subjects (Rashid M., 2006).

Another study were done in Poland (Powazka K., 2002) to determine the possible effects of occupational noise on workers, showed that the high exposure workers had significantly increased systolic blood pressure levels, compared with the low exposure men with an averages of 125 mmHg vs. 121 mm Hg.

In Germany and other developed countries as many as 4 to 5 million that is 12-15% of all employed people, are exposed to noise levels of 85 dB(A) or more. That results in 20% or more of employers suffer from hearing impairment (WHO, 2001). In 1998 to 2000, it was estimated that approximately 28 million Americans suffer from hearing loss and almost 10 million Americans suffer from noise induced hearing loss (NIHL) (Rabinowitz P., 2000).

Locally, in Palestine especially in West Bank, the problem of noise has been studied in some regions. Noise pollution in the community of Arraba was studied as an example of the country side regions which are 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 has been found that the L_{eq} values for 60% of the selected locations are exceeding 65.0 dB (A). This result is obviously higher than the adopted international standards. Accordingly, the area of Arraba town is considered an unacceptable living area (Abdel-raziq I., 2000). In Nablus city a study was conducted to investigate noise pollution practices by measuring the equivalent noise level in a large sample of factories. It has been found that the L_{eq} values for 40% of the selected factories are higher than the adopted international standards. These factories are considered noisy sources to workers (Abdel-Ali M. M., 2001).

1.3 Objectives of this Study

Human being has increasingly been exposed to different types of pollution. Mainly, noise pollution which has growing severe effects on human health.

In Palestine, the lack of data collected about noise effects on blood oxygen saturation, especially in the factories whose noise levels above 90 dB(A) is the encouraging reason to conduct this study. As a result of this study, some suggestions and recommendations for the workers and the owners of the factories are expected. Consequently, this will reduce noise pollution and its effects on people in every aspect of life.

The aims of this study are:

1. Measuring noise levels generated by different machines sources in factories.

2. Determining the effect of occupational noise on blood oxygen saturation, hearing threshold levels, systolic and diastolic blood pressure and pulse rate in the range (90-110) dB(A) level.

3. Comparing the effects of noise pollution on blood oxygen saturation in the range (80-90) dB(A) and (90-110) dB(A) levels.

Chapter Two
Theoretical Background

This chapter consists of four sections including nature of sound (sec. 2.1), explanation of some basic information about noise (sec. 2.2), several sources of noise (sec. 2. 3), and the effects of noise on humans (sec. 2.4).

2.1 Nature of Sound

Sound is a mechanical wave that results from pressure variations, or oscillations, in an elastic medium like water, air, and solids. The motion of the particles is parallel and anti parallel to the direction of the energy transport. This is what characterizes sound waves as longitudinal waves. A longitudinal wave consists of a succession pattern of compressions and rarefactions. Thus, the wavelength is defined as the distance from one compression to the next adjacent compression or the distance from one rarefaction to the next adjacent rarefaction (Jennifer L., 2009). Sometimes, sound wave is called a **pressure wave**, since it consists of a succession pattern of high and low pressure regions moving through a medium.

2.2 Noise Pollution

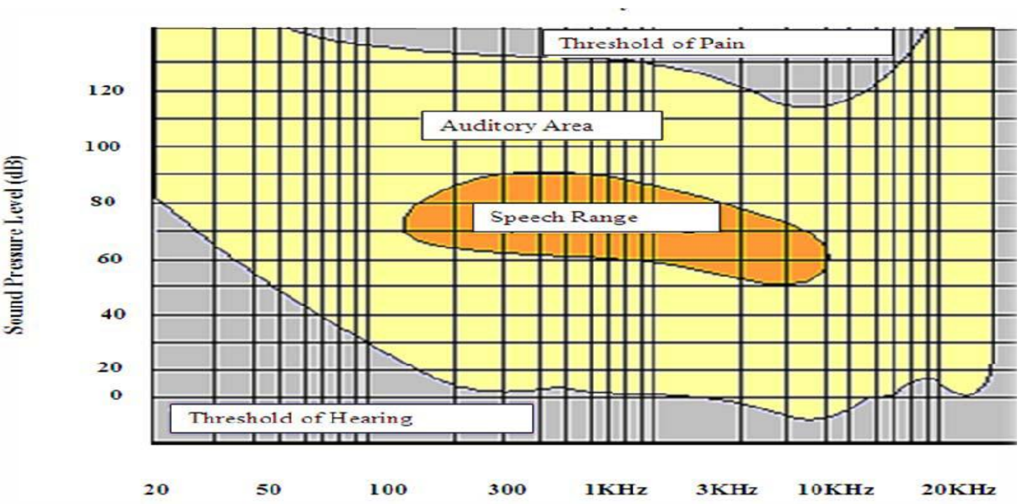
Noise has always been an important environmental problem**. The traditional definition of noise is unwanted or disturbing sound. However**, sound becomes unpleasant when it interferes with normal activities such as sleeping, conversation, and disrupts one's quality of life. Because noise pollution is an invisible problem, enough attention has not been given to control it as other types of pollution like air pollution and water pollution (Goines L., 2007).

In this section, the audible range for human beings (sec. 2.2.1), measuring noise levels (sec. 2.2.2), sound level meters, (sec. 2.2.3), and frequency weighting (sec. 2.2.4).

2.2.1 The Audible Range for Human Beings

The human audible frequency range from 20 (Hz) to 20 (kHz). Frequencies out of this range are not detected by human ear. The ear is not equally sensitive to all the frequencies. The non audible frequencies come in two regions, the infrasonic region below 20 Hz and the ultrasonic region above 20 kHz as can be seen in

(Fig 2.1).



Frequency (Hz)

(Fig. 2.1): Sound pressure level in dB as a function of frequency in Hz, of the audible frequency range for human beings (Purdom P. W., 1980)

The lowest curve on the chart gives the threshold of hearing at - various frequencies – which is defined as the level of a sound at which, under specified conditions, a person gives 50% correct detection responses on repeated trials. On the other hand the uppermost curve on the chart gives the threshold of SPL at which the ear starts to feel pain at different frequencies. However, the most audible frequencies are between 1000 and 4000 HZ (Purdom P. W., 1980).

2.2.2 Measuring Noise Levels

Many types of measuring systems can be used for the measurement of sound, depending on the purpose of the study, and the characteristics of the sound. Any measuring system consists of various elements which are (Malchaire J. 1994):

a. Transducer (microphone).

b. Electronic amplifier.

c. Frequency weighting.

d. Data storage facilities.

e. Display.

2.2.3 Sound PressureLevel

Sound pressure level (SPL) is a logarithmic measure of the effective sound pressure of a sound relative to a reference value. It is usually measured in decibels (dB) above a standard reference level (2×10^{-5} Pascal).

All measured sound pressures are referenced to a standard pressure that corresponds roughly to the threshold of hearing at 1000 Hz. Thus, the sound pressure level indicates how much greater the measured sound is greater than this threshold of hearing. Because the human ear can detect a wide range of sound pressure levels, they are measured on a logarithmic scale with units of decibels (dB) (Stumpf F. B., 1980).

Sound pressure level is defined mathematically as:

$$SPL\ (dB) = 20 \log (p/ P_{ref}).$$

Where:

SPL is the Sound pressure level in dB.

P is the measured sound pressure.

P_{ref} is the threshold of hearing pressure for human beings which is about 2×10^{-5} Pascal (Pa). So the threshold level takes the value zero decibels (Stumpf F. B., 1980).

The equivalent continuous sound pressure level (SPL), or sometimes called (L_{eq}) is the most common quantity used to measure the sound level.

The equivalent continuous sound pressure level (L_{eq}) can be calculated according to this formula.

$L_{eq} = L_{NP} - (L_{10} - L_{90})$

Where L_{NP} is the noise pollution level,

L_{10} represents the noise level exceeded at 10% of the measured time.

L_{90} represents the noise level exceeded at 90% of the measured time (Stumpf F. B., 1980).

2.2.4 Frequency Weighting

The human ear is not equally sensitive to sound at different frequencies as can be seen in Fig 2.1. For this purpose, frequency weighting filters have been developed. Sound pressure levels are reduced or increased as a function of frequency before being combined together to give an overall level. There are different weighting filters A, B, and C. The internationally standardized weighting network in common use is the (A) network. This network has been built to correlate sound to the frequency response of the human ear for different sound levels. It is a useful simple means of describing interior noise environments. When frequency weighting filters are used, the measured noise levels can be designated specifically by dB(A) when A weighting is used *(Colin.H.H, 1994).*

2.3 Sources of Noise

This section describes various sources of noise which are emitted from the environment. Which are: industrial noise (sec. 2.3.1), transportation noise (sec. 2. 2. 2), noise from buildings services and construction noise (sec.2. 2. 3), and domestic noise (sec. 2.3.4).

2.3.1 Industrial Noise

The sound pressure level generated depends mainly on the type of the noise source, distance from the source to the receiver, and the nature of the working environment. For a given machine, the sound pressure levels depend on the part of the total mechanical or electrical energy that is transformed into acoustical energy.

There are many sources of noise in industrial machinery and processes include: rotors, gears, turbulent fluid flow, impact processes, electrical machines, internal combustion engines, drilling, crushing, pumps and compressors.

It can be observed from the following examples that the industrial processes produce insensitive amount of noise:

- Valves can generate sound levels of 105 dB(A).

- In Wood working industry the sound levels of saws is approximately 106 dB(A).

- In industries such as paper and saw mills. The mean sound levels range between 92 and 96 dB(A), and the recorded peak values for SPL were between 117 and 136 dB(A) (Samir N.Y., 2001).

Because of occupational hazard, control technology should aim at reducing noise to acceptable levels by action on the work environment. The Occupational Safety and Health Administration (OSHA) in the U.S. puts the industrial noise standards that guarantee the workers health, such as the OSHA permissible noise exposure (OSHA, 2004).

(Table 2.1): OSHA permissible noise exposures

Time permitted per day (hour)	**Sound Level (dB)**
16	85
12	87
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

2.3.2 Transportation Noise

Transportation noise includes road traffic (sec.2.3.2.1), and air traffic noises (sec.2.3.2.2).

2.3.2.1 Road Traffic

Road traffic is the major cause of human exposure to noise, especially for people living near airports and railway lines. In the city, the main sources of traffic noise are the motors and exhaust systems of autos, smaller trucks, buses, and motorcycles. Noise from the motors and exhaust systems of large trucks provides the major portion of highway noise effects, and leads to a potential noise hazard to the driver. (Alice H., 1991).

In a road traffic noise study in Belgrade, 253 residents exposed to road traffic noise levels of larger than 65 dB(A), experienced significantly more fatigue, depression, nervousness and headaches, compared to residents exposed to lower than 55dB(A) (Belojevic G., 1997).

A community study in 366 Japanese women suggests that road traffic noise only has effects on depression, fatigue and irritability above a threshold of 70 dB(A) (Yoshida, 1997).

2.3.2.2 Air Craft

Air transport brings very important economic and social benefits to the countries that have airports.

Aircraft landing and taking off are the main sources of noise. Noise comes from landing has become the dominant reason for complaints at some airports. In addition, people who live close to airports may experience ground noise from sources on the airport such as taxiing aircraft, and aircraft engine tests. Previous studies have found associations between exposure to aircraft noise and performance as well as health. Chronic exposure to aircraft noise leads to elevating blood pressure and annoyance (U.K. Government, 2003).

2.3.3 Noise from Construction and Building Services

Building construction can cause considerable noise emissions. A variety of sounds come from cranes, cement mixers, hammering, boring and other work processes. Because much of the work is carried out in the open, noises are difficult to be controlled. Machinery or equipments which have annoying-loud sound and are used too early or late in the day can be a real cause of discomfort and stress to the neighbors(Sinclair J.D.N., 1995).

Noise exposure levels of construction workers are difficult to determine due to the day to day difference in occupation process, shift length of each worker and seasonal nature of the job. Nevertheless, it is obvious that the construction worker is exposed to very high sound levels during the work hours (Sinclair J.D.N., 1995).

2.3.4 Domestic Noise

Domestic noise can be a significant source of annoyance to the members of the society. The volume, intensity, duration and time of the day all influence the level of annoyance. In residential areas, noise may stem from mechanical devices like: heat pumps and ventilation system, as well as voices, music and other kinds of sounds generated by neighbors. Domestic noise also includes noise from boilers, plumbing equipment, air conditioners, and generators. Noise created by Loudspeakers used in public places is responsible for creating noise of high amplitude (WHO, 1995).

2.4 Effects of Noise on Health

Noise pollution is becoming a major public health concern with all of its biological and social effects on the body. Noise produces direct adverse health effects on people like: tinnitus, tension, headaches, higher cholesterol levels, irritability insomnia. Some of these effects on humans have been studied in this study and are being discussed in the following subsections: blood oxygen saturation (sec. 2.4.1), blood pressure and hypertension (sec. 2.4.2), heart rate (sec.2.4.3), and hearing (sec.2.4.4).

2.4.1 Blood Oxygen Saturation

Blood oxygen saturation is defined as the ratio of oxyhemoglobin to the total concentration of hemoglobin present in the blood (Oxyhemoglobin

+ reduced hemoglobin). When arterial oxyhemoglobin saturation is measured by pulse oximetry, it is called SPO_2.

One hemoglobin molecule can carry a maximum of four molecules of oxygen. If a hemoglobin molecule carries three molecules of oxygen, then it carries 3/4 or 75% of the maximum amount of oxygen it could carry.

"For example, 1000 hemoglobin molecules can carry a maximum of 4000 oxygen molecules; if they were carrying 3600 oxygen molecules, then the oxygen saturation level would be (3600/4000)*100 or 90%" (*Schutz A.*, 1982).

Healthy blood oxygen saturation is between 95 and 100 percent. Patients with blood oxygen levels below 90 percent are considered to have hypoxemia, and a blood oxygen level below 80 percent is known as severe hypoxemia. Shortness of breath is the primary symptom of hypoxemia (Michael K., 2007).

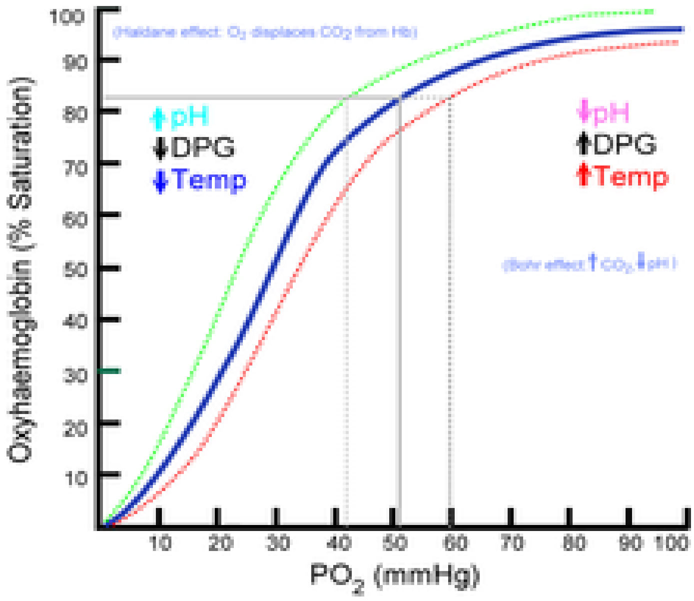
Blood oxygen saturation level can be determined using a pulse oximeter. A pulse oximeter is a particularly convenient measurement instrument. Typically it has a pair of small light-emitting diodes (LEDs) facing a photodiode through a transparent part of the patient's body, usually a fingertip. One LED is red, with wavelength of 660 nm, and the other is infrared with wavelengths 905nm or 940 nm. Absorption at these wavelengths differs significantly between oxyhemoglobin and its deoxygenated form. Therefore, the oxyhemoglobin /deoxyhemoglobin ratio can be calculated from the ratio of the absorption of the red and infrared light (Millikan C. A., 2004).

2.4.1.1 Oxygen–Hemoglobin Dissociation Curve

The oxyhemoglobin dissociation curve is an important way for understanding how blood carries and releases oxygen. Specifically, the oxyhemoglobin dissociation curve specializes in oxygen saturation (SPO_2) and partial pressure of oxygen in the blood (PO_2), and it is determined by hemoglobin's affinity for oxygen, that is, how readily hemoglobin captures and releases oxygen molecules from its surrounding tissue(Richard A., 2007).

In its usual shape, the oxyhemoglobin dissociation curve (Fig 2.2) describes the relation between the blood oxygen saturation (y axis) and the partial pressure of oxygen (x axis). Hemoglobin's affinity for oxygen increases as successive molecules of oxygen bind. When the oxygen partial pressure increases more molecules will bind until the saturation is being reached. The curve has a sigmoidal or S-shape. When the pressure is above 60 mmHg, the standard dissociation curve is approximately flat, which means that the blood oxygen content does not change significantly even with large increases in the oxygen partial pressure (Richard A., 2007).

It is observed from the graph that when the blood oxygen saturation is 50%, the partial pressure of oxygen is about 26.6 mmHg for a healthy person, and it is known as the P_{50}. The P_{50} is a conventional measure of hemoglobin affinity for oxygen. In the presence of disease or other conditions that change the hemoglobin's oxygen affinity, the curve would shift to the right or left, so that the P_{50} changes accordingly. An increased P_{50} points to a rightward shift of the standard curve, which means that a larger partial pressure is necessary to keep 50% oxygen saturation. This shows a decreased affinity. In contrast, a lower P_{50} points to a leftward shift and a higher affinity (Richard A., 2007).



(Fig. 2.2): Oxyhemoglobin Dissociation Curve (Richard A., 2007).

2.4.2 Blood Pressure and hypertension

2.4.2.1 Blood Pressure

Blood pressure is the force of blood against the artery walls as it circulates through the body. During each heartbeat, blood pressure varies between a maximum (systolic) and a minimum (diastolic) pressure

(Richard E., 2005). Blood pressure is written as two numbers, the first number represents the systolic pressure when the heart beats. And the second represents the diastolic pressure when the heart rests between beats. A person's blood pressure is usually expressed in terms of the systolic pressure over diastolic pressure (mmHg), for example 120/80 mmHg (WHO 2011).

Average values for arterial pressure could be computed for any given population, there is often a large variation from person to person; arterial pressure also varies in individuals from moment to moment. In a study of 100 human subjects without a known history of hypertension, an average blood pressure of 112/64 mmHg was found, which are currently classified as normal values (Westfal R.E., 2001).

There are various factors, such as age and gender that influence blood pressure average values. In children, the normal ranges are lower than for adults. In the elderly, blood pressure tends to be above the normal adult range, largely because of reduced flexibility of the arteries. Moreover individual's blood pressure varies with noise, exercise, emotional reactions, and sleep (Pickering, 2005).

2.4.2.2 Hypertension

Hypertension or high blood pressure is defined as a chronic medical condition in which the blood pressure in the arteries is increased. So in order to circulate blood through vessels heart must work harder than normal. Normal blood pressure is at or below 120/80 mmHg. And high blood pressure is considered to be present if it is at or above 140/90 mmHg.

In people aged 18 years or older, hypertension is defined as an increase in one or both systolic and diastolic blood pressure values higher than an accepted normal value (139 mmHg for systolic and 89 mmHg for diastolic) (Oparil S., 2000).

Causes of hypertension (Jones D.W., 2003):

- Noise pollution has significant evidences associating with Hypertension disease.
- Age, risk for hypertension increases with age.
- Personal habits such as eating too much salt (sodium), being overweight, lack of exercise, drinking too much alcohol and smoking.
- Diabetes, about 60% of people who have diabetes also have hypertension.

2.4.3 Pulse Rate

Pulse rate is determined by the number of heartbeats per unit time, typically expressed as beats per minute (beats/min). The following is the normal pulse rate for different ages (Bernstein D., 2007).

- Newborns (0-30 days old): 70 - 190 beats/min.

- Infants (1 - 11 months old): 80-120 beats/min.
- Children 1 to 10 years: 70 - 130 beats/min.
- Children over 10 and adults: 60 - 100 beats/min.

2.4.4 Hearing

Sound is sensed in the human ear, which acts as a transducer or microphone. Sound waves are transformed by the ear into nerve impulses. The brain interprets the nerve impulses as sound (Berenice G., 2001).

2.4.4.1 Hearing Impairment

The experience of partial or complete loss of hearing in one or both ears may be due to exposure to chemicals that damage the organs of the ear, exposure to excessive noise, and age (ACGIH, 2006). Conductive hearing impairment is reversible, which occurs in the outer and middle ear, while that occurs in the inner ear is irreversible. In work place, workers exposed to noise exposures greater than 85 dB(A) have an eight percent risk of experiencing hearing impairment (NIOSH, 1998).

2.4.4.2 Noise-Induced Hearing Loss

Noise-induced hearing loss (NIHL) is a type of hearing loss that occurs by exposure to domestic and occupational noise. It results in the damage of the hair cells of the cochlea in the inner ear, which are important structures of the inner ear responsible for converting sound energy to electrical signals that transmitted to the brain. In general, it was found that the amount of noise required to cause permanent damage from chronic exposure is more than 85 dB(A) for 10 years or more, with more than 8 hours a day (Rabinowitz, P., 2000).

Chapter Three
Methodology

3.1 Study Sample

This study was conducted on a group of workers (involving male and female) who worked in various types of factories distributed in several locations in Jenin city: food, stonecutter, clothes (sewing machines), concrete, carpentry and metal factories.

The sample of this study were 115-worker, including 96 male and 19 female, distributed in these different factories. The sample's ages were between 18-60 years. The subjects chosen had no history of heart, cardiovascular disease, and hearing impairment. In addition the selected workers had at least a one year work, with average working hours (8-12 hours) per day. Moreover the workers were asked not to smoke or to eat salty food before taking the measurements, because these factors affect blood pressure.

In order to select study sample from a random one the following formula was used: (Cochran 1977).

$$M = n / \{1+ [n/N]\} \qquad (3.1)$$

Where:

M: correlation sample size that should be used.

n: best value to select a random sample of workers in each factory = Z^2 P q/ δ^2.

N: the actual sample number of workers that found in each factory.

$\delta = 0.055$

Z = 1.96 (constant)

P = 0.9, q = 1-P = 0.1

The (Table 3.1) below shows the number of examined workers in each factory.

(Table 3.1): Number of examined workers in each factory.

Plant type / name	Number of examined workers
Metal (hadad factory)	20 male
Chemical (Albareeq factory)	15 male
Concrete	21 male
Food	10 male
Sewing(Clothes)	19 female, 10 male
Stonecutter	15 male
Carpentry	5 male

3.2 Stages of Study

This study was conducted between October and November 2011. Field measurements were carried out in central locations in each industrial plant in order to fulfill the objectives of this study.

Several stages were performed:

1. Choosing the industrial plants and measuring the sound pressure levels of these plants.

2. Classifying the factories into different categories according to sound pressure levels in the range (80-90 dB(A)) and (90-110 dB(A)).

3. Visiting the chosen factories to inform them about the nature of the study and taking the permission for doing the measurements on their workers.
4. Regular visits to these factories were done in order to measure several health parameters during the morning shift and after 6 hours working (between 7.00am and 13.00 pm). However the tested parameters are summarized as:

    a. Blood oxygen saturation.

    b. Hearing threshold.

    c. Arterial blood pressure (systolic and diastolic).

    d. Pulse rate.

3.3 Measurements and Instrumentations

During our work, several instruments and tools were used in performing our test and measurements. These instruments are briefly described in the following subsections, sound pressure level measurement (sec. 3.3.1), blood oxygen saturation (sec 3.3.2), hearing threshold (sec. 3.3.3), and blood pressure and pulse rate (sec.3.3.4).

3.3.1 Sound Pressure Level Measurement

Sound Level Meter was used to measure the sound levels of selected factories, it composed of a microphone that converts the sound signal to an equivalent electrical signal, which varies with the acoustical signal. And because the signal is quite small, it must pass through amplifier of weighting network, weighting network type A was used in this study. The amplified signal was then passed through ammeter and the value of root mean square (RMS) was determined by a detector (Diehl, 1973).

The Sound Pressure Level Meter used in this study is shown in (Fig 3.1) and has an accuracy of ± 0.5 dB(A) at 25ºC, with precision of 0.1 dB(A) (Instructions Manual for Sound Level Meter 1998 b).

(Fig. 3.1): Sound pressure level meter model 2900 type 2 (Instructions manual 1998 b).

The sound level meter was placed in different locations in each factory in order to read the average sound level. These readings were taken every ten minutes before working and after 6 hours of working, then the average of these readings were taken.

3.3.2 Blood Oxygen Saturation

Blood oxygen saturation was taken for every worker twice a day, before starting the work and after 6 hours of beginning working. The instrument used for this purpose was Pulse -Oximeter LM-800 (Finger - Oximeter) with accuracy ± 2%

(Fig 3.2).

(Fig. 3.2): Pulse Oximeter LM-800 ((Instructions manual 2012).

3.3.3 Hearing Threshold

To evaluate the subject's hearing ability an Audiometer (Instruction Manual, 2010) with accuracy ±3%, at operating temperatures 15 degree centigrade to 40 degree centigrade (Fig 3.3) was used for different workers at different frequencies; 250, 500, 1000, 2000, 4000.6000. 8000 HZ. The results of left and right ear were recorded.

(Fig. 3.3): Manual Audiometer (Instruction Manual, 2010)

3.3.4 Blood pressure and Pulse rate

The blood pressure (systolic and diastolic) and pulse rate were measured for each selected worker twice a day before work (pre-exposure), and after 6 hours from beginning work (after-exposure) by Automatic Digital Electronic Wrist Blood Pressure Monitor (Fig 3.4), (model WS-300) with accuracy ± 3 mm-Hg, and ± 5% for reading heart pulse rate with operating temperature range of +10 ºC to +40 ºC (Instruction manual 1998 a).

(Fig. 3.4): Arterial Blood Pressure and Heart Pulse Rate Meter, model WS-300 (Instruction manual 1998 a).

3.4 Statistical Analysis

The gathered data were digitalized in a database developed with SPSS and Microsoft excel program. The measurements will be analyzed statistically as the following:

- Pearson correlation factor (R) and the probability (P) were used to measure the strength correlation between noise pollution levels and the dependant variable, and between the dependent variables before and after exposure to noise. Values with $P < 0.05$ were considered statistically significant.

- Analysis of variance test (ANOVA) was used in this study, to detect associations between noise level as independent variables and blood oxygen saturation, pulse rate, arterial blood pressure(systolic and diastolic), and hearing threshold level as dependent variables.

Chapter Four
Experimental Measurements

This chapter with its four sections represents the results of this study. Measurements of occupational noise levels are explained in (sec 4.1). Measurements of health effects of noise pollution are shown in (sec 4.2). Data analysis of the dependent variables and sound pressure levels in (sec 4.3). Finally, personal health effects dependence are presented in (sec 4.4).

4.1 Measurements of Occupational Noise Levels

An acoustical environmental measurements were carried out in seven selected industrial plants distributed in different regions in Jenin city. This study sample consisted of one hundred and fifteen workers (96 male, 19 female). The mean age of this study sample was 35.22 yr, the mean duration of employment was 6.99 yr, and the mean working hours was 9 hours per day.

In this study it has been tried to investigate the effects of occupational noise pollution on the workers in selected factories. Many variables such as blood oxygen saturation, arterial blood pressure (systolic and diastolic), pulse rate, and hearing threshold levels were measured and analyzed in order to find relationship between those variables and sound pressure level.

The measured equivalent sound levels (L_{eq}) in all selected industrial plants are presented in Table 4.1. Number of selected workers and working hours per day in each selected plant are also shown in this table.

(Table 4.1): Noise pollution levels (NPL) in dB(A) at the studied plants.

Plant type/Name	**L_{eq} in dB(A) Mean value**	**Number of selected workers**	**Working hours per day**
Metal (Hadad factory)	95.6	20 male	12
Chemical (Albareeq factory)	93.7	15 male	9
Concrete	102.4	21 male	8
Food	82.5	10 male	8
Sewing(Clothes)	90.2	19 female, 10 male	10
Stonecutter	110.5	15 male	8
Carpentry	85.5	5 male	8

The L_{eq} values of sound pressure levels (SPL) in all studied plants ranged from 82.5 dB(A) to 110.5 dB(A), with mean value of (94.34) dB(A). It can be observed that the studied factories have L_{eq} values that don't correspond with working hours per day as OSHA illustrated in (Table 2.1). The industrial plants in this study can be divided into two groups according to their sound pressure levels, the first group: factories with SPL more than 90 dB(A), and the second with SPL less than 90 dB(A).

4.2 Measurements of Health Effects of Noise Pollution

In this section the health effects on some dependent variables such as: blood oxygen saturation (SPO_2%), pulse rate (PR), arterial blood pressure (systolic (SBP) and diastolic (DBP)) (sec 4.2.1), and hearing threshold levels (HTL)) (sec 4.2.2) are discussed.

4.2.1 Blood Oxygen Saturation, Pulse Rate, and Arterial blood pressure (systolic and diastolic) Measurements

Minimum, maximum, mean, and standard deviation of mean values of duration of employment, age, blood oxygen saturation (SPO_2%), pulse rate (P.R), systolic and diastolic pressure (SBP & DBP) [before (b) and after (a) exposure to noise] for all selected workers in each industrial plants are presented in (Table 4.2) and for the two groups of factories are presented in (Table 4.3). The net change of blood oxygen saturation, pulse rate, and blood pressure (systolic and diastolic) before and after exposure to noise in the two groups of factories are shown in (Table 4.4). Minimum, maximum, mean, and standard deviation values for male & female in sewing factory were presented in (Table 4.5) and for the whole study population are shown in (Table 4.6).

(Table 4.2): Minimum (Min), maximum (Max), mean, and standard deviation (S.D) values of studied variables for selected workers from each industrial plant.

Variables	F_1				F_2				F_3				F_4			
	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D
Duration of employment(year)	2	25	10.30	6.92	1	10	3.26	3.01	2	15	6.90	3.37	3.00	17.00	7.30	5.33
Age (year)	20	60	37.15	9.41	97	99	98.33	0.61	24	58	41.38	9.75	22.00	47.00	31.20	8.23
SPO_2 %(b)	97	99	98.15	0.67	95	98	96.86	0.83	98	99	98.33	0.48	98.00	99.00	98.70	0.48
SPO_2 %(a)	94	98	96.40	0.94	18	47	27.00	9.46	95	98	96.95	0.80	97.00	98.00	97.50	0.52
P.R (b) beats/min	69	86	79.25	5.57	55	86	69.46	9.18	57	105	78.52	10.51	65.00	79.00	69.60	4.71
P.R (a) beats/min	72	90	81.95	5.59	58	89	73.26	8.67	64	107	82.23	10.24	69.00	81.00	72.30	4.29
S.B.P (b) mmHg	120	142	128.05	5.05	111	133	122.80	5.34	108	146	128.09	7.30	123.00	133.00	127.10	3.07
S.B.P (a) mmHg	124	145	130.80	5.13	120	140	127.66	5.35	124	163	133.80	8.29	127.00	137.00	130.20	3.48
D.B.P(b) mmHg	73	87	79.80	3.53	65	87	74.86	5.62	59	100	81.38	8.78	70.00	82.00	76.70	4.21
D.B.P (a) mmHg	75	91	82.75	3.72	69	92	78.06	5.89	65	105	85.80	8.69	74.00	85.00	79.60	3.27

Variables	F_5				F_6				F_7			
	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D
Duration of employment(year)	1.00	10.00	3.89	2.55	2	18	12.66	4.11	2	11	5.60	3.57
Age (year)	19.00	52.00	32.72	8.83	24	48	40.13	7.29	26	50	34.20	9.75
SPO_2 %(b)	98.00	99.00	98.37	0.49	97	99	98.40	0.63	98	99	98.40	0.54
SPO_2 %(a)	95.00	98.00	96.82	0.71	94	97	96.20	1.01	97	97	97.00	0.00
P.R (b) beats/min	56.00	92.00	76.51	7.89	69	89	79.20	6.15	69	79	72.80	3.76
P.R (a) beats/min	59.00	95.00	80.27	7.83	74	94	83.86	6.36	72	81	75.80	3.70
S.B.P (b) mmHg	100.00	139.00	127.24	7.27	119	147	130.66	8.69	122	130	127.20	3.27
S.B.P (a) mmHg	109.00	153.00	132.51	8.26	126	158	137.60	9.61	126	137	131.00	4.06
D.B.P(b) mmHg	56.00	92.00	78.65	8.57	70	92	80.46	7.60	76	82	79.20	2.58
D.B.P (a) mmHg	59.00	95.00	82.55	8.62	75	112	87.66	9.72	79	85	81.80	2.77

** SPO_2%:

Blood oxygen saturation, P.R: Pulse rate (beats/ min), SBP: Systolic blood pressure (mmHg), DBP: Diastolic blood pressure (mmHg), b: Before exposure to noise, a: after exposure to noise.

** F1: Metal (Haddad), F2: Chemical (ALbareeq), F3: Concrete, F4: Food, F5: Sewing (Clothes), F6: Stonecutter, F7: Carpentry.

(Table 4.3): Minimum (Min), maximum (Max), mean, and standard deviation (S.D) values of studied variables for two groups of factories.

Variables	Factories with SPL > 90 dB(A)				Factories with SPL < 90 dB(A)			
	Min	Max	Mean	S.D	Min	Max	Mean	S.D
Duration of employment(year)	1	25	7.03	5.38	2	17	6.73	4.75
Age (year)	18	60	35.68	10.13	22	50	32.33	8.61
SPO_2 %(b)	97	99	98.32	0.56	98	99	98.53	0.51
SPO_2 %(a)	94	98	96.68	0.87	96	98	97.20	0.56
P.R (b) beats/min	55	105	76.83	8.60	65	79	71.13	4.40
P.R (a) beats/min	58	107	80.51	8.46	69	81	73.93	4.30
S.B.P (b) mmHg	100	147	127.43	7.09	122	136	127.86	3.71
S.B.P (a) mmHg	109	163	132.48	7.98	126	144	131.60	4.85
D.B.P(b) mmHg	56	100	79.16	7.46	70	84	78.00	4.19
D.B.P (a) mmHg	59	112	83.37	8.11	74	89	81.00	3.87

(Table 4.4): Net change of blood oxygen saturation, pulse rate, and blood pressure (systolic and diastolic) before and after exposure in two groups of factories.

Difference between means	Factories for SPL more than 90 dB(A)	Factories for SPL less than 90 dB(A)
SPO_2%	1.64	1.33
P.R beats/min	3.68	2.8
S.B.P mmHg	5.05	3.73
D.B.P mmHg	4.21	3

(Table 4.5): Minimum (Min), maximum (Max), mean, and standard deviation (S.D) values for male & female in sewing factory.

Variables	Male				Female			
	Min	Max	Mean	S.D	Min	Max	Mean	S.D
Duration of employment(year)	1.00	7.00	3.40	1.77	1.00	10.00	4.15	2.89
Age (year)	21.00	45.00	32.50	7.24	19.00	52.00	32.84	9.74
SPO_2 %(b)	98.00	99.00	98.20	0.42	98.00	99.00	98.47	0.51
SPO_2 %(a)	95.00	98.00	96.40	0.84	96.00	98.00	97.05	0.52
P.R (b) beats/min	70.00	87.00	78.00	4.89	56.00	92.00	75.73	9.10
P.R (a) beats/min	74.00	88.00	81.90	4.65	59.00	95.00	79.42	9.07
S.B.P (b) mmHg	123.00	136.0	130.0	4.39	100.0	139.0	125.78	8.13
S.B.P (a) mmHg	129.00	145.0	136.0	5.53	109.0	153.0	130.68	8.97
D.B.P(b) mmHg	70.00	92.00	82.30	6.78	56.00	90.00	76.73	8.94
D.B.P (a) mmHg	77.00	95.00	86.90	5.91	59.00	95.00	80.26	9.07

(Table 4.6): Minimum (Min), maximum (Max), mean, and standard deviation (S.D) values for whole study population.

Variables	Min	Max	Mean	S.D
Duration of employment (year)	1	25	6.99	5.29
Age (year)	18	60	35.22	9.98
SPO_2 %(b)	97	99	98.35	0.56
SPO_2 %(a)	94	98	96.76	0.86
P.R (b) beats/min	55	105	76.02	8.44
P.R (a) beats/min	58	107	79.59	8.37
S.B.P (b) mmHg	100	147	127.39	6.70
S.B.P (a) mmHg	109	163	132.21	7.57
D.B.P(b) mmHg	56	100	78.94	7.10
D.B.P (a) mmHg	59	112	82.97	7.71

4.2.2 Hearing Threshold Measurements

Percentage of degrees of hearing impairment according to different organizations: OSHA, NIOSH & ASHA, and EPA's definitions in each industrial plant is presented in Tables 4.7- 4.9.

(Table 4.7): Percentage of degrees of hearing impairment in each studied industrial plant [according to OSHA's definition of hearing impairment].

Industrial Plants	SPL (dB(A)	Right ear (b) %	Right ear (a) %	Left ear (b) %	Left ear (a) %
F_1	95.6	8/ 20 (40%)	11/ 20 (55%)	9/ 20 (45%)	14/ 20 (70%)
F_2	93.7	2/15(13%)	4/15 (26%)	2/15 (13%)	5/15 (33%)
F_3	102.4	9/21(42%)	14/21 (66%)	8/21 (38%)	11/21 (52%)
F_4	82.5	2/10 (20%)	3/10 (30%)	1/10 (10%	2/10 (20%)
F_5	90.2	Male: 2/10 (20%) Female: 5/19 (26%) Total: 7/29 (24%)	Male: 4/10 (40%) Female: 10/19 (52%) Total: 14/29 (48%)	Male: 3/10 (30%) Female: 6/19 (31%) Total: 9/29 (31%)	Male: 5/10 (50%) Female: 11/19(57%) Total: 16/29 (55%)
F_6	110.5	7/15 (46%)	10/15 (66%)	6/15 (40%)	10/15(66%)
F_7	85.5	1/5 (20%)	1/5(20%)	2/5(40%)	2/5 (40%)
Total	_______	36/115 (31%)	57/115 (49%)	37/115 (32%)	60/115 (52%)

Average of hearing threshold levels in either one or both ears exceed 25 dB(A) at 1000, 2000, and 3000 Hz. ** F_1: Metal (Haddad), F_2: Chemical (ALbareeq), F_3: Concrete, F_4: Food, F_5: Sewing (Clothes), F_6: Stonecutter, F_7: Carpentry.

(Table 4.8): Percentage of degrees of hearing impairment in each studied industrial plant [according to NIOSH and ASHA's definition of hearing impairment].

Industrial Plants	SPL (dB(A)	Right ear (b) %	Right ear (a) %	Left ear (b) %	Left ear (a) %
F_1	95.6	3/ 20 (15%)	10/ 20 (50%)	3/ 20 (15%)	10/ 20 (50%)
F_2	93.7	1/15 (6.6%)	4/15 (26%)	2/16 (13%)	4/15 (26%)
F_3	102.4	7/21 (33%)	12/21 (57%)	5/21 (23%)	10/21 (47%)
F_4	82.5	1/10 (10%)	2/10 (20%)	1/10 (10%)	2/ 10(20%)
F	90.2	Male: 2/10 (20%) Female: 4/19(21%) Total: 6/29 (20%)	Male: 5/10(50%) Female: 9/19 (47%) Total: 14/29 (48%)	Male: 3/10(30%) Female: 4/19 (21%) Total: 7/29 (24%)	Male: 6/10(60%) Female: 10/19(52%) Total: 16/29 (55%)
F_6	110.5	4/15 (27%)	8/15 (53%)	3/15 (20%)	7/15 (46%)
F_7	85.5	1/5 (20%)	1/5(20%)	1/5 (20%)	2/5 (40%)
Total	———	23/115 (20%)	51/115 (44%)	22/115 (19%)	51/115 (44%)

Average of hearing threshold levels in either one or both ears exceed 25 dB(A) at 1000, 2000, 3000, and 4000 Hz.

** F_1: Metal (Haddad), F_2: Chemical (ALbareeq), F_3: Concrete, F_4: Food, F_5: Sewing (Clothes), F_6: Stonecutter, F_7: Carpentry.

(Table 4.9): Percentage of degrees of hearing impairment in each studied industrial plant [according to EPA's definition of hearing impairment].

Industrial Plants	SPL dB(A)	Right ear (b) %	Right ear (a) %	Left ear (b) %	Left ear (a) %
F_1	95.6	11/ 20 (55%)	16/ 20 (80%)	12/ 20 (60%)	16/20 (80%)
F_2	93.7	4/15 (26%)	6/15 (40%)	4/15 (26%)	7//15 (46%)
F_3	102.4	11/21 (52%)	17/21 (80%)	9/21 (42%)	15/21(71%)
F_4	82.5	2/10 (20%)	3/10 (30%)	2/10(20%)	3/10 (30%)
F_5	90.2	Male: 3/10 (30%) Female: 7/19 (36%) Total: 10/29 (34%)	Male: 6/10(60%) Female: 12/19 (63%) Total: 18/29 (62%)	Male: 3/10 (30%) Female:10/19 (52%) Total: 13/29 (44%)	Male: 6/10 (60%) Female: 13/19(68%) Total: 19/29 (65%)
F_6	110.5	9/15 (60%)	12/15 (80%)	9/15 (60%)	12/15(80%)
F_7	85.5	1/5 (20%)	1/5 (20%)	2/5 (40%)	2/5(40%)
Total	______	48/115(41%)	73/115 (63%)	51/115(44%)	74/115(64%)

Average of hearing threshold levels in either one or both ears exceed 25 dB(A) at 500, 1000, and 2000 Hz.

** F_1: Metal (Haddad), F_2: Chemical (ALbareeq), F_3: Concrete, F_4: Food, F_5: Sewing (Clothes), F_6: Stonecutter, F_7: Carpentry.

From Tables (4.7- 4.9) it can be observed that workers suffer from permanent hearing impairment before taking the measurements. That's because long duration of employment which ranges from (1-25 year) with mean of 6.99 year. But the percentages of workers suffer from hearing impairment increase after exposure to occupational noise.

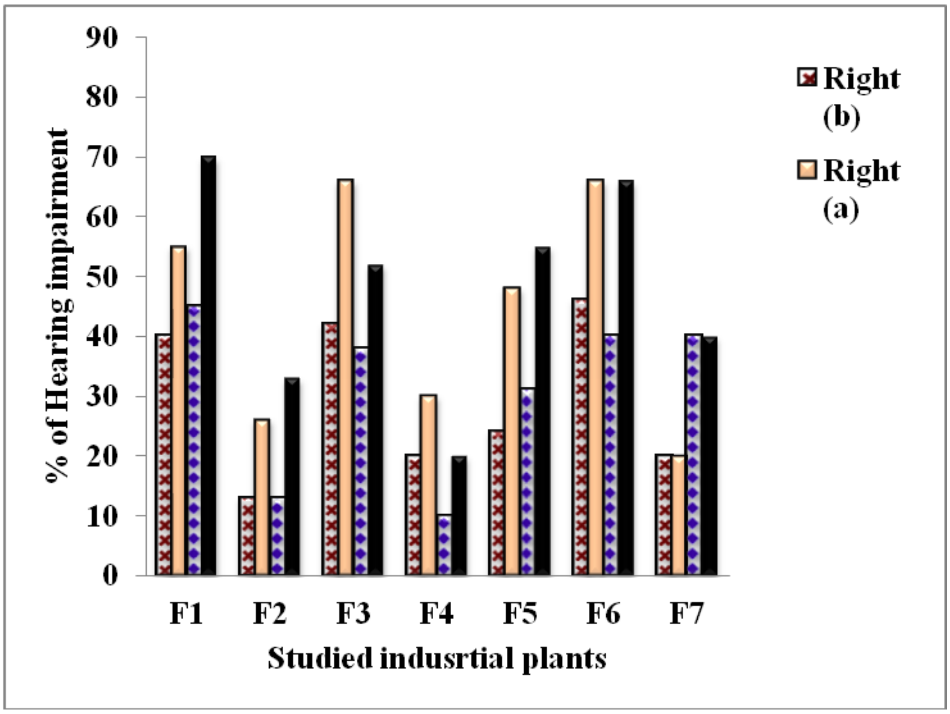
Based on (Table 4.7), a total of 31% of the selected workers were classified to have hearing impairment according to OSHA [average of hearing levels in either or both ears exceed 25 dB(A) at 1000, 2000, and 3000 Hz] in their right ear and 32% in their left ear, when they were examined before exposure to occupational noise. On the other hand, 49% of the selected workers were classified to have hearing impairment in their right ear and 52% in their left ear, when they were examined after exposure to occupational noise.

In (Table 4.8), a total of 20% of the selected workers were classified to have hearing impairment according to NIOSH and ASHA [average of hearing levels in either or both ears exceed 25 dB(A) at 1000, 2000, 3000, and 4000 Hz] in their right ear and 19% in their left ear, when they were examined before exposure to occupational noise. On other hand, 44% of the selected workers were classified to have hearing impairment in their both right and left ear, when they were examined after exposure to occupational noise.

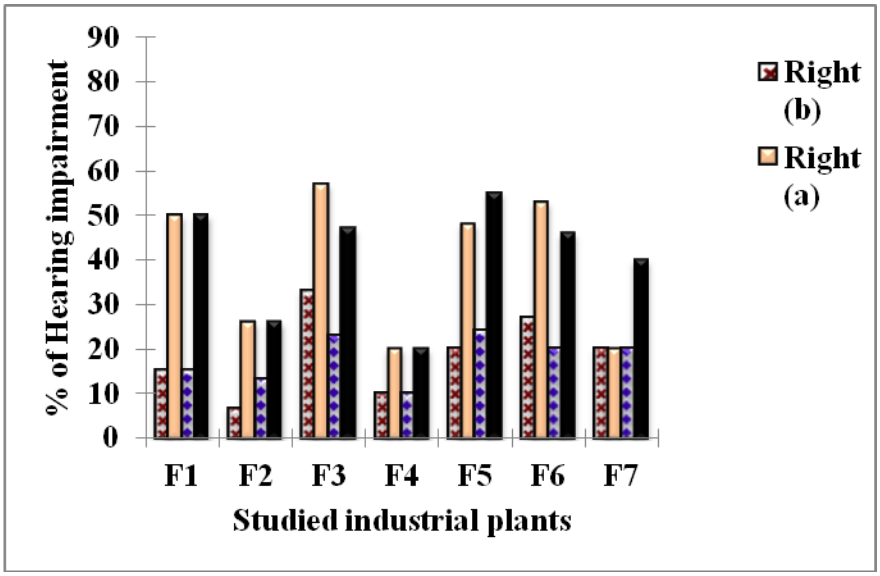
In (Table 4.9), a total of 41% of the selected workers were classified to have hearing impairment according to EPA [average of hearing levels in either or both ears exceed 25 dB(A) at 500, 1000, and 2000 Hz] in their right ear and 44% in their left ear, when they were examined before exposure to occupational noise. Otherwise, 63% of the selected workers were classified to have hearing impairment in their right ear and 64% in their left ear, when they were examined after exposure to occupational noise.

Percentage of degrees of hearing impairment in right and left ears of selected workers, when they were examined before and after exposure to noise in the industrial plant [according to OSHA, NIOSH & ASHA, and EPA's definition of hearing impairment] is graphically displayed in (Figs 4.1- 4.3).

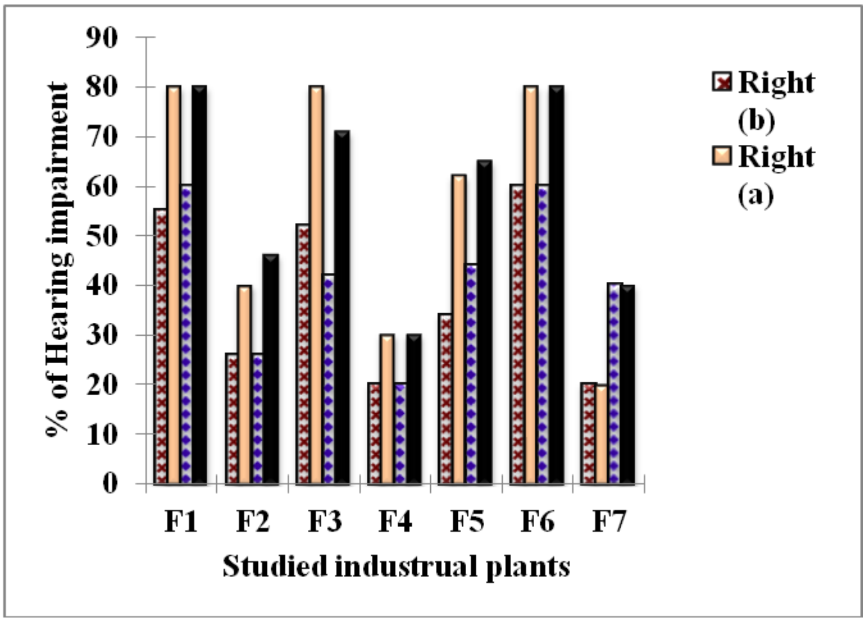
(Figs 4.1- 4.3) show that there is a significant shift in percentage of hearing impairment in both ears in different industrial plants before and after exposure to occupational noise.



(Fig. 4.1): Percentage of degrees of hearing impairment in right ear & left ear of subjects before (b) and after (a) exposure to occupational noise in each industrial plant [according to OSHA's definition of hearing impairment].



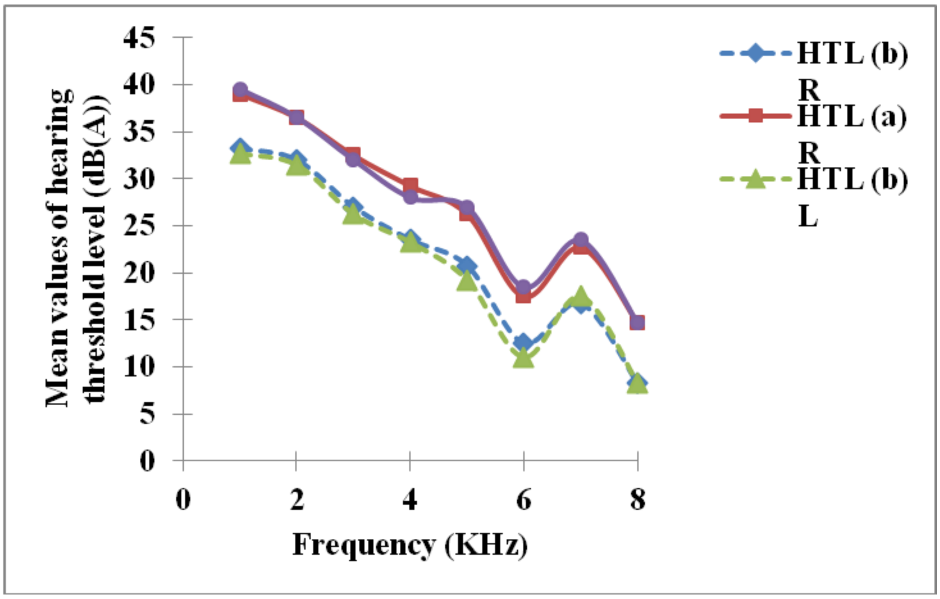
(Fig. 4.2): Percentage of degrees of hearing impairment in right ear & left ear of subjects before (b) and after (a) exposure to occupational noise in each industrial plant [according to NIOSH and ASHA's definition of hearing impairment].



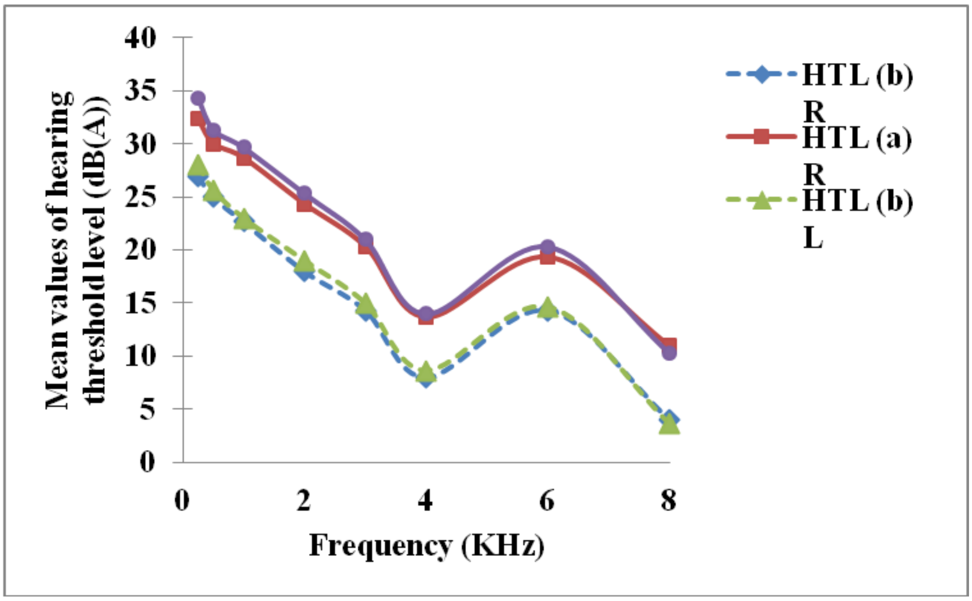
(Fig. 4.3): Percentage of degrees of hearing impairment in right ear & left ear of subjects before (b) and after (a) exposure to occupational noise in each industrial plant [according to EPA's definition of hearing impairment].

In (Figs 4.4-4.10) the hearing threshold levels (HTL) of left and right ears for all study sample were plotted as function of frequency. These figures showed the mean values of hearing threshold levels (HTL) of right and left ears change with different frequencies, before and after exposure to occupational noise in the selected factories.

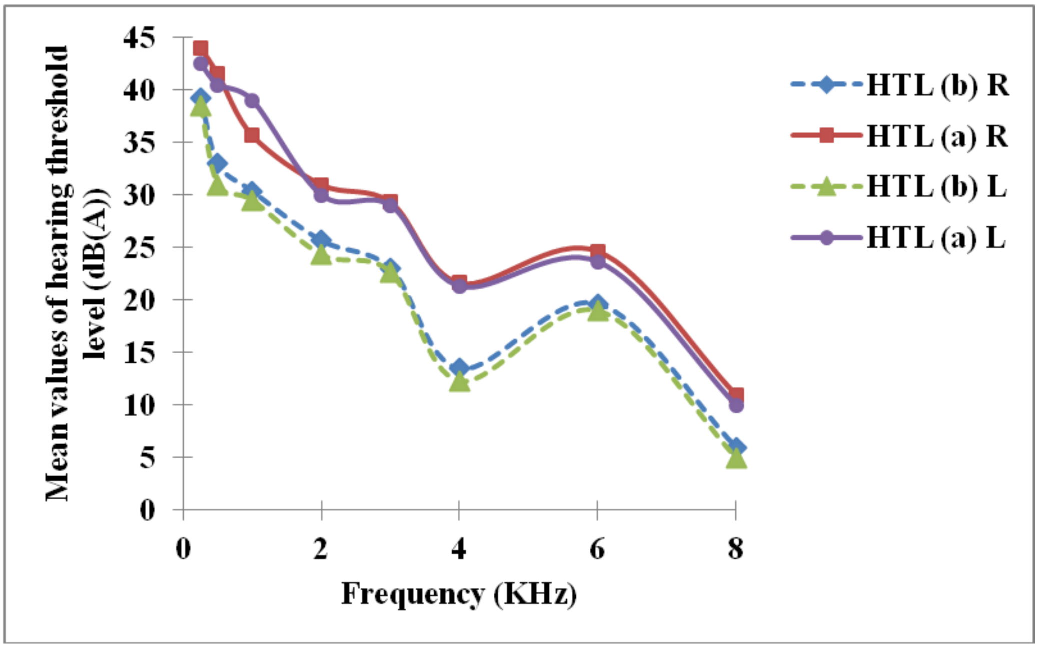
It can be observed that there are significant hearing threshold shifts in right and left ears of workers in different plants, before exposure to occupational noise (pre-exposure) and after 6 hours from exposure to noise.



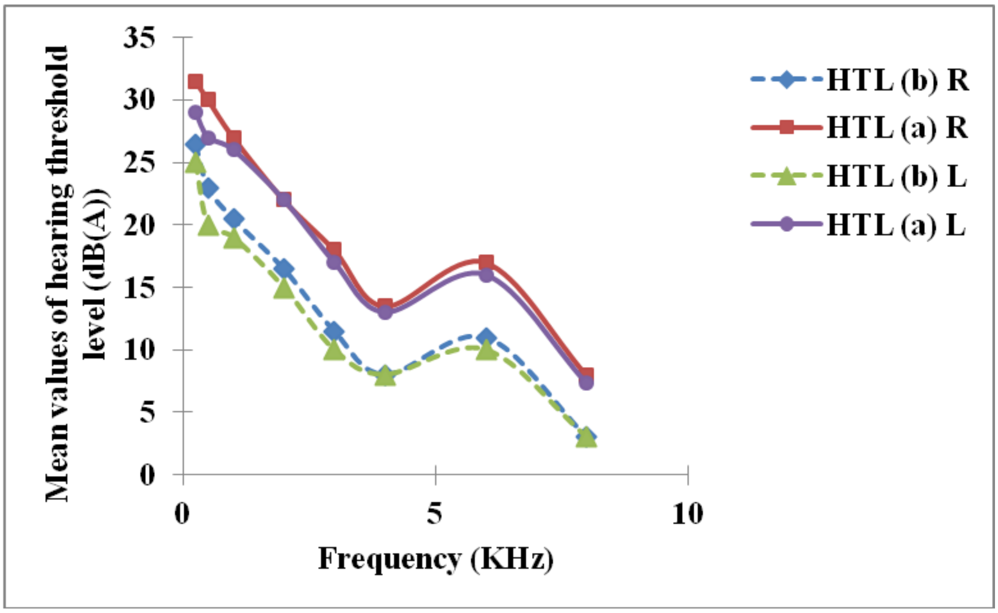
(Fig. 4.4): Mean values of hearing threshold level (HTL) of right (R) and left (L) ears before (b) and after (a) exposure to occupational noise in Metal (Haddad Factory) according to different frequencies.



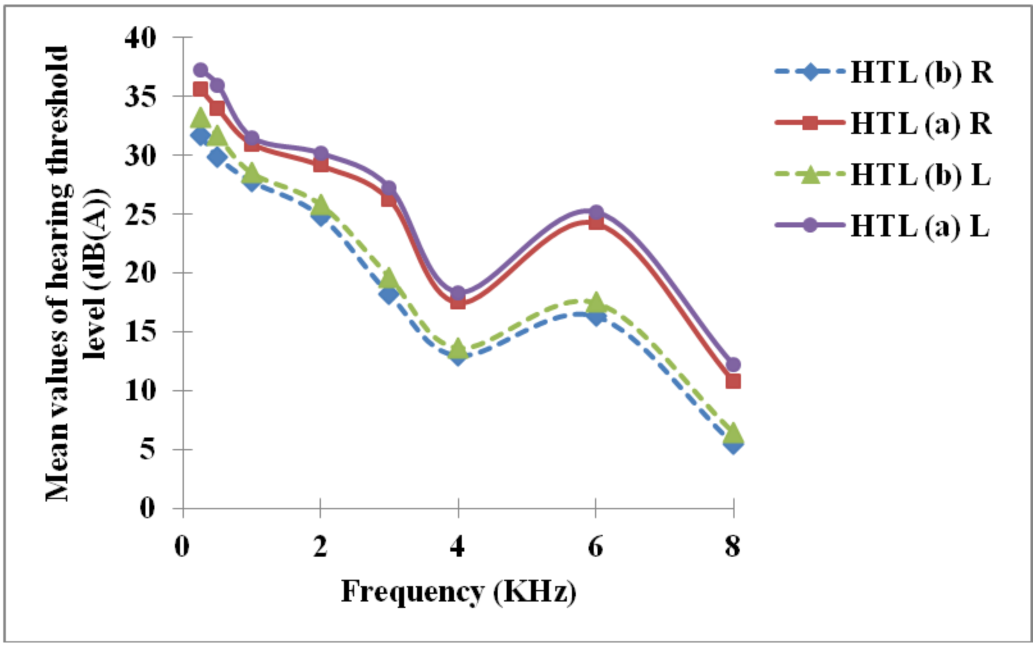
(Fig. 4.5): Mean values of hearing threshold level (HTL) of right (R) and left (L) ears before (b) and after (a) exposure to occupational noise in chemical (AlbareeqFactory) according to different frequencies.



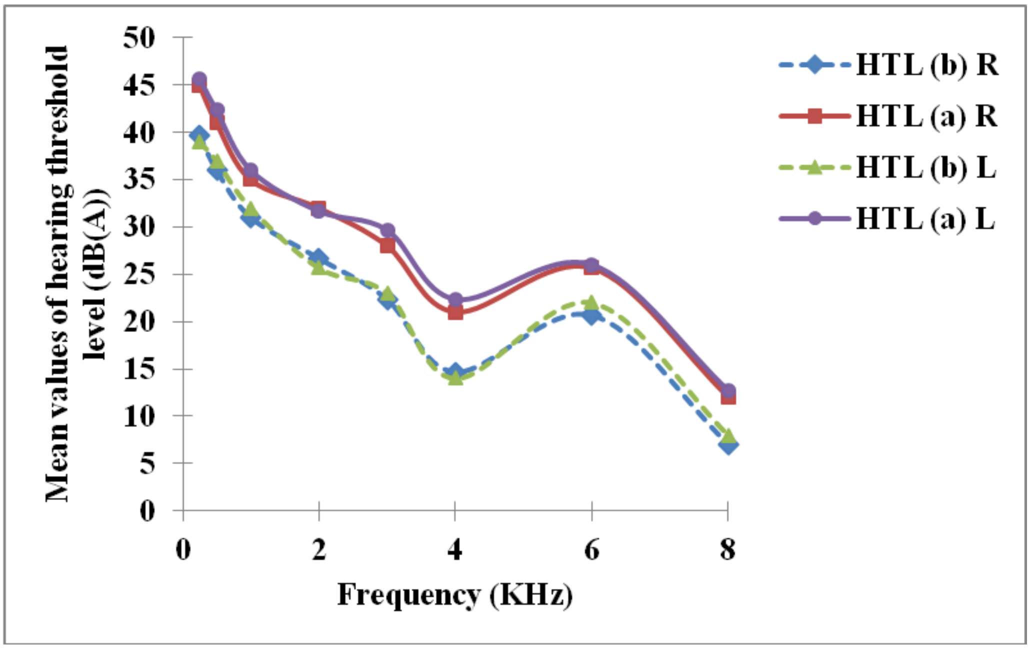
(Fig. 4.6): Mean values of hearing threshold level (HTL) of right (R) and left (L) ears before (b) and after (a) exposure to occupational noise in Concrete Factory according to different frequencies.



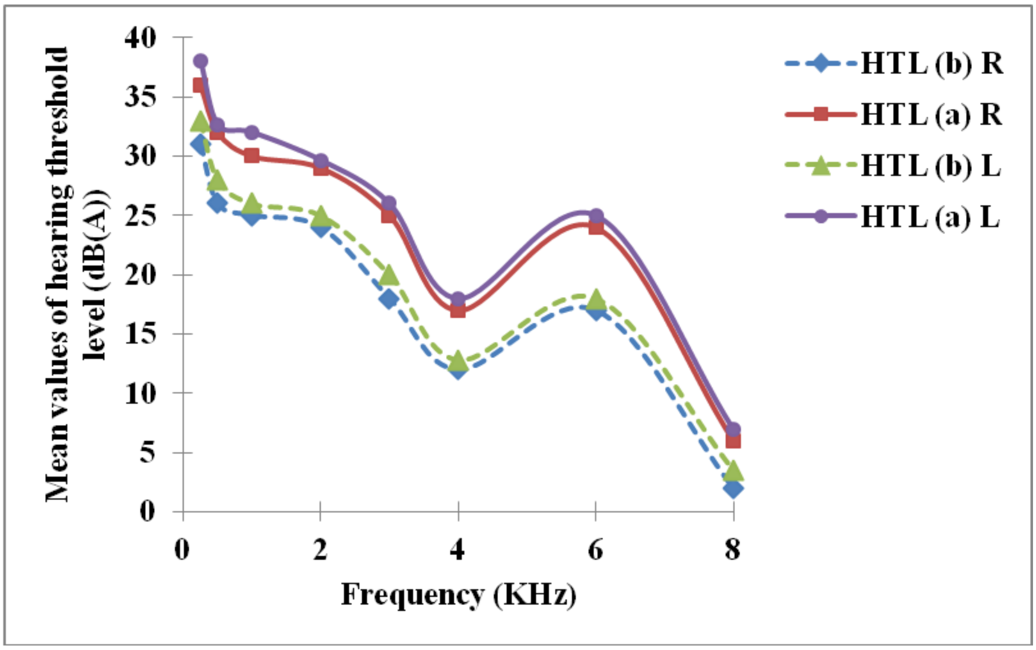
(Fig. 4.7): Mean values of hearing threshold level (HTL) of right (R) and left (L) ears before (b) and after (a) exposure to occupational noise in Food Factory according to different frequencies.



(Fig. 4.8): Mean values of hearing threshold level (HTL) of right (R) and left (L) ears before (b) and after (a) exposure to occupational noise in Sewing Factory according to different frequencies.



(Fig. 4.9): Mean values of hearing threshold level (HTL) of right (R) and left (L) ears before (b) and after (a) exposure to occupational noise in Stonecutter according to different frequencies.



(Fig. 4.10): Mean values of hearing threshold level (HTL) of right (R) and left (L) ears before (b) and after (a) exposure to occupational noise in Carpentry according to different frequencies.

4.3 Data Analysis of Dependent Variables and Sound Pressure Levels in the Studied Factories

Results of sound pressure levels (SPL), blood oxygen saturation, pulse rate, blood pressure, and hearing threshold levels showed that there is strong positive correlation (Pearson Correlation Coefficient) between sound pressure levels (SPL) as an independent variables and blood oxygen saturation, pulse rate, systolic and diastolic pressure (SBP, DBP), and hearing threshold levels (HTL) at different frequencies as dependent variables (Table 4.10).

Paired sample tests of blood oxygen saturation, pulse rate, systolic and diastolic pressure (SBP, DBP), and hearing threshold levels (HTL) at different frequencies 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 4.11).

The dependence of the mean values of blood oxygen saturation, pulse rate, systolic and diastolic pressure (SBP, DBP) of workers on sound pressure levels (SPL) in each studied industrial plant is displayed in (Figs 4.11- 4.14).

(Table 4.10): Pearson correlation coefficient between sound pressure levels (SPL) in dB(A) and blood oxygen saturation (SPO_2%), pulse rate (P.R), arterial blood pressure (SBP &DBP), and hearing threshold levels (HTL) at different frequencies.

Independent variable, dB(A)	Dependent variables	Pearson correlation coefficient (R)	Probability (P)
SPL	SPO2%	0.779	0.039
SPL	P.R	0.790	0.035
SPL	SBP	0.734	0.030
SPL	DBP	0.795	0.033
SPL	R 250 Hz	0.877	0.009
SPL	L 250 Hz	0.935	0.002
SPL	R 500 Hz	0.891	0.007
SPL	L 500 Hz	0.945	0.001
SPL	R 1000 Hz	0.914	0.004
SPL	L 1000 Hz	0.954	0.001
SPL	R 2000 Hz	0.715	0.071
SPL	L 2000 Hz	0.738	0.058

SPL	R 3000 Hz	0.747	0.054
SPL	L 3000 Hz	0.790	0.035
SPL	R 4000 Hz	0.826	0.022
SPL	L 4000 Hz	0.874	0.010
SPL	R 6000 Hz	0.626	0.133
SPL	L 6000 Hz	0.720	0.068
SPL	R 8000 Hz	0.645	0.118
SPL	L 8000 Hz	0.663	0.104

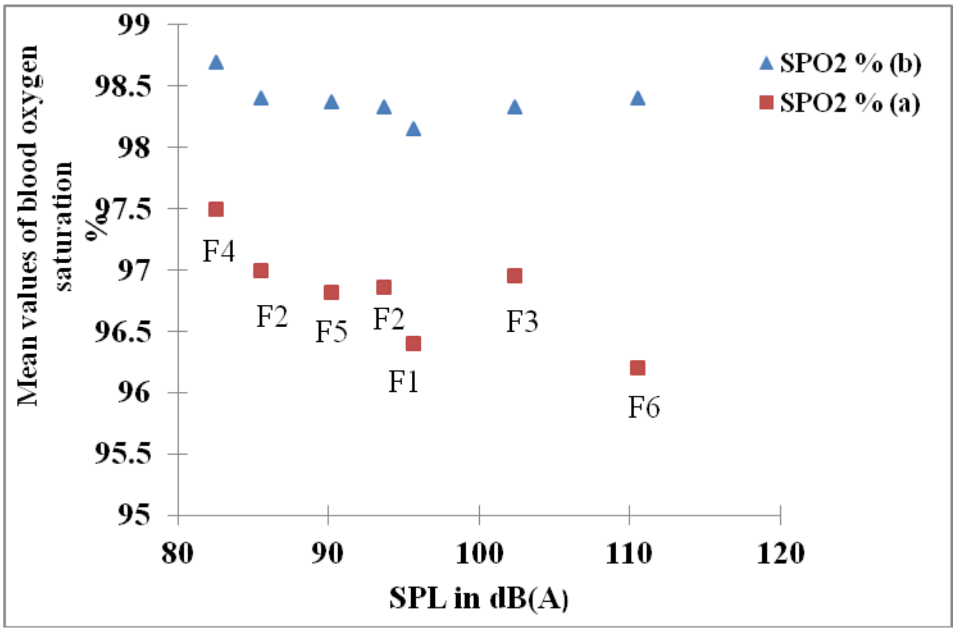
SPL: Sound pressure level in dB(A), SPO_2%: Blood oxygen saturation, P.R: Pulse rate (beats/ min), SBP: Systolic blood pressure (mmHg), DBP: Diastolic blood pressure (mmHg), R: Right ear, L: Left ear, 250-8000 Hz: Frequencies which were used to detect the hearing levels of workers.

(Table 4.11): Paired samples correlation of all studied variables before (b) and after (a) exposure to occupational noise in all studied industrial plants.

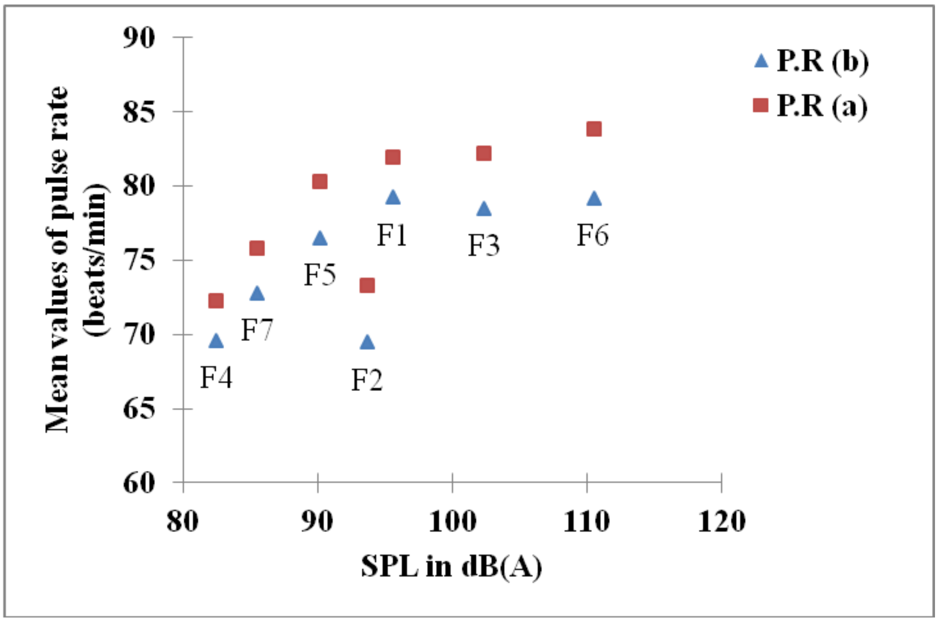
Paired variables	Pearson correlation coefficient (R)	Probability (P)
$SPO_{2\,\%}$ (b) & $SPO_{2\,\%}$(a)	0.714	0.042
P.R (b) & P.R (a)	0.990	0.000
S.B.P (b) & S.B.P (a)	0.891	0.003
D.B.P (b) & D.B.P (a)	0.906	0.002
R 250 Hz (b) & R 250 Hz (a)	0.994	0.000
L 250 Hz (b) & L 250 Hz (a)	0.992	0.000

R 500 Hz (b) & R 500 Hz (a)	0.964	0.000
L500 Hz (b) & L 500 Hz (a)	0.933	0.000
R 1000 Hz (b) & R 1000 Hz (a)	0.990	0.000
L 1000 Hz (b) & L 1000 Hz (a)	0.991	0.000
R 2000 Hz (b) & R 2000 Hz (a)	0.981	0.000
L 2000 Hz (b) & L 2000 Hz (a)	0.987	0.000
R 3000 Hz (b) & R 3000 Hz (a)	0.927	0.003
L 3000 Hz (b) & L 3000 Hz (a)	0.913	0.002
R 4000 Hz (b) & R 4000 Hz (a)	0.938	0.002
L 4000 Hz (b) & L4000 Hz (a)	0.911	0.001
R 6000 Hz (b) & R 6000 Hz (a)	0.951	0.001
L 6000 Hz (b) & L 6000 Hz (a)	0.905	0.001
R 8000 Hz (b) & R 8000 Hz (a)	0.923	0.001
L 8000 Hz (b) & L 8000 Hz (a)	0.947	0.001

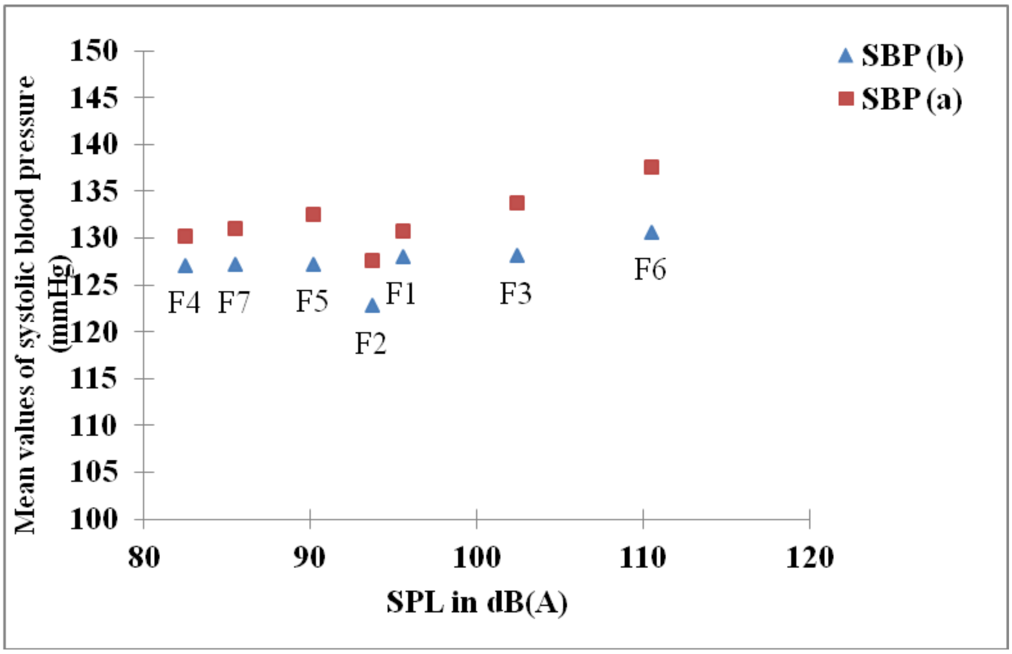
SPO_2%: Blood oxygen saturation, P.R: Pulse rate (beats/min), SBP: Systolic blood pressure (mmHg), DBP: Diastolic blood pressure (mmHg), R: Right ear, L: Left ear, b: Before exposure to noise, a: after exposure to noise, and 250-8000 Hz: Frequencies which were used to detect the hearing levels of workers.



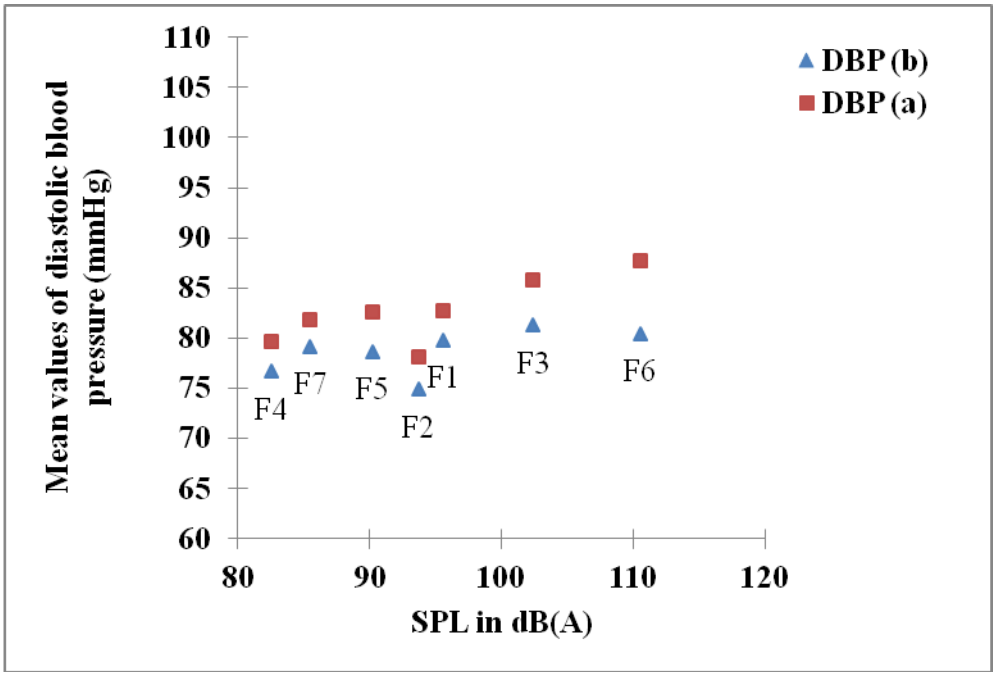
(Fig. 4.11): Mean values of blood oxygen saturation (SPO_2%) of workers according to sound pressure levels (SPL) in each industrial plant.



(Fig. 4.12): Mean values of pulse rate (P.R) of workers according to sound pressure levels (SPL) in each industrial plant.



(Fig. 4.13): Mean values of systolic blood pressure (SBP) of workers according to sound pressure levels (SPL) in each industrial plant.



(Fig. 4.14): Mean values of diastolic blood pressure (DBP) of workers according to sound pressure levels (SPL) in each industrial plant.

4.4 Personal Health Effects Dependence

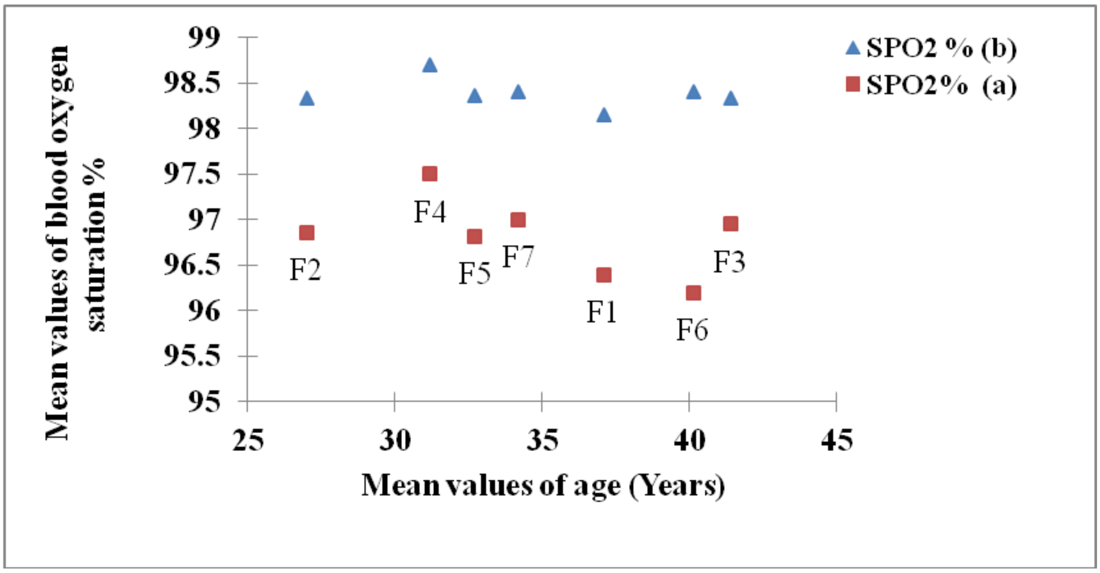
In this section some personal health effects such as age (sec 4.4.1) and duration of employment (sec 4.4.2) are discussed.

4.4.1 Age Health Effects Dependence

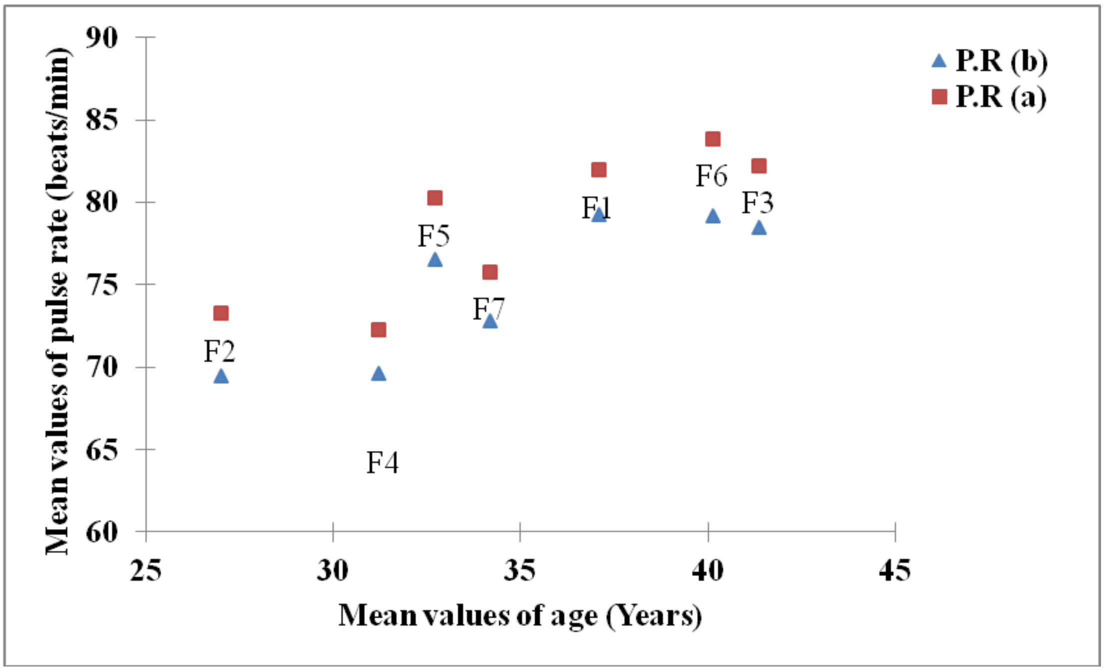
The dependence the mean values of blood oxygen saturation, pulse rate, arterial blood pressure (systolic and diastolic) on the age of workers in the studied industrial plants is represented in (Figs 4.15 - 4.18).

It can be observed that there are significant interactions between mean values of blood oxygen saturation, pulse rate, arterial blood pressure (systolic and diastolic), and the age of workers in the studied industrial plants.

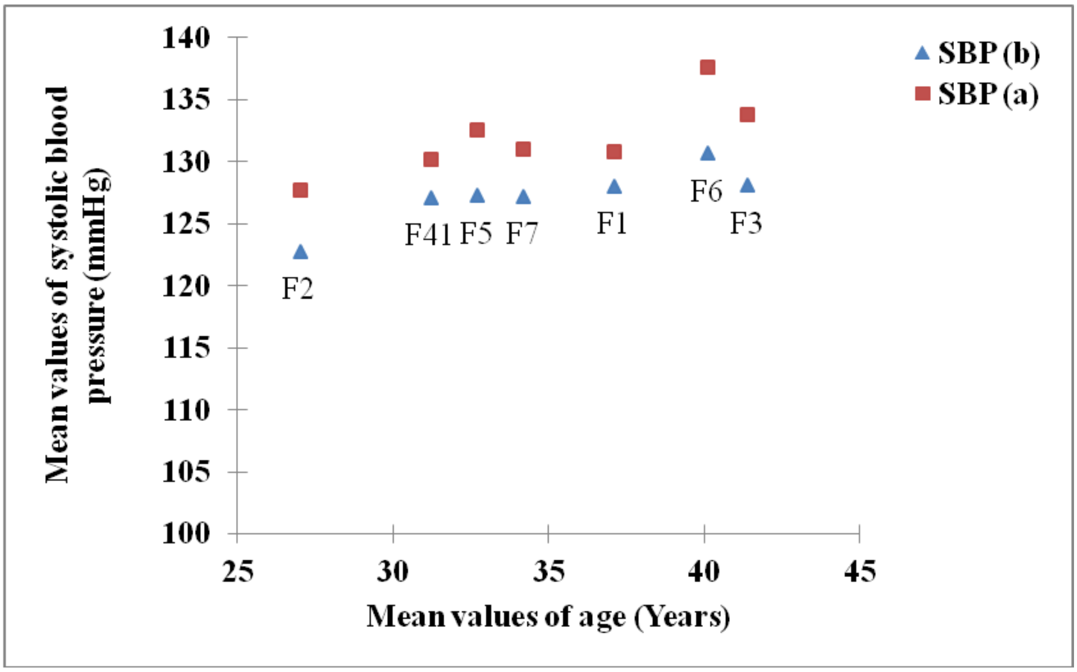
Comparison of the different age groups showed that the mean values of blood oxygen saturation were lower among the oldest workers. While the pulse rate, and the arterial blood pressure (systolic and diastolic), and hearing threshold level were significantly higher among the oldest workers (Figs 4.19-4.22), (Fig. 4.23).



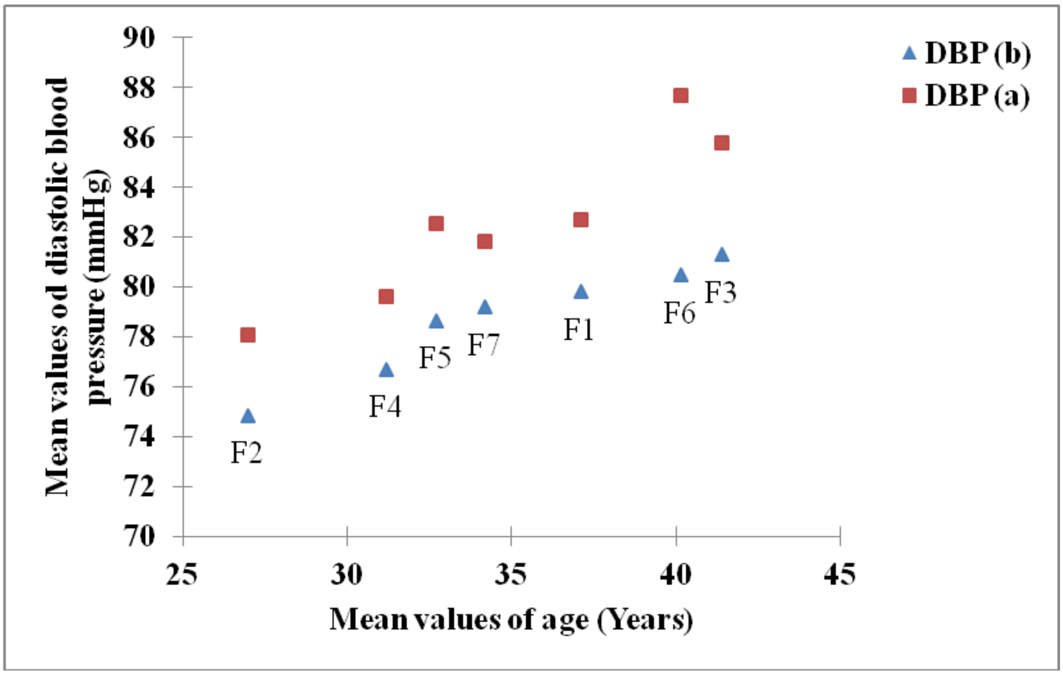
(Fig. 4.15): Means values of blood oxygen saturation (SPO_2%) of workers by mean values of age in each industrial plant.



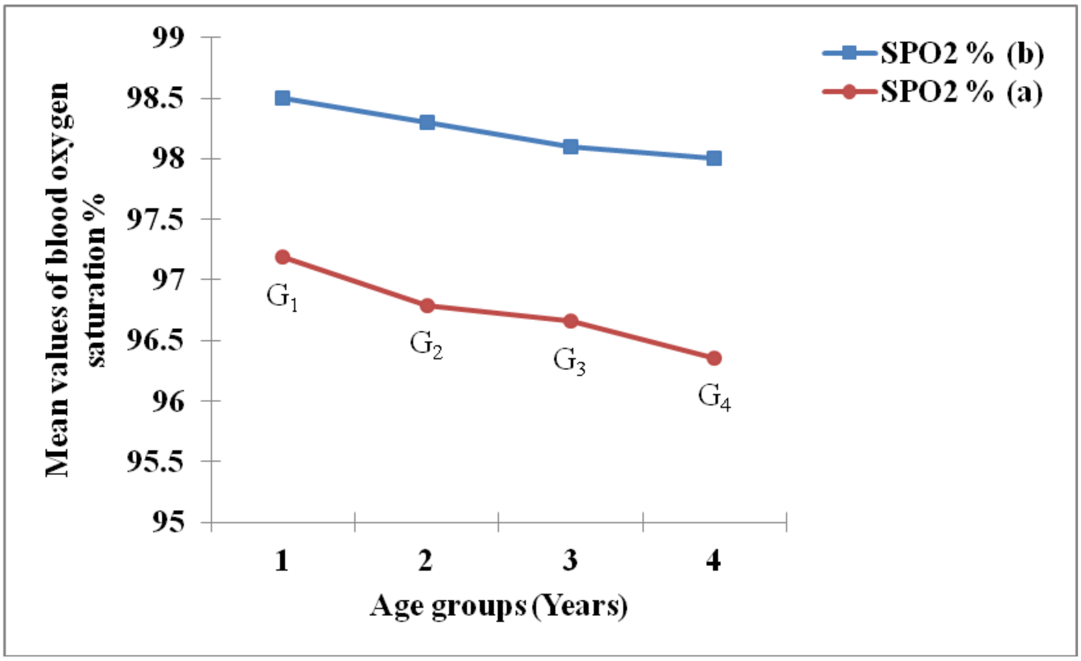
(Fig. 4.16): Means values of pulse rate (P.R) of workers by mean values of age in each industrial plant.



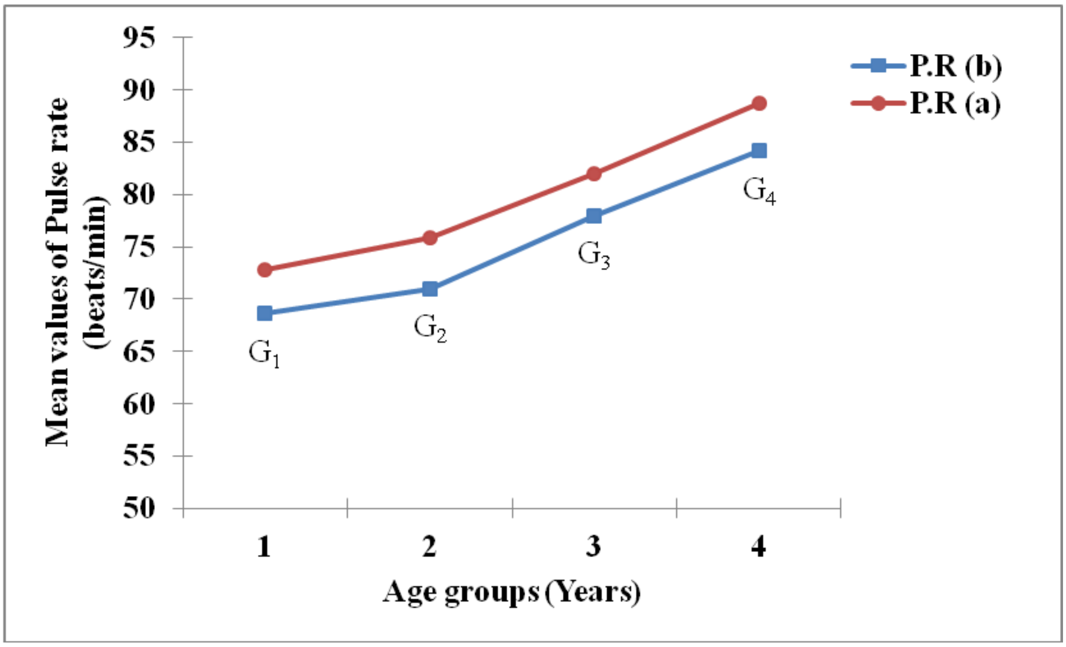
(Fig. 4.17): Means values of systolic blood pressure (SBP) of workers by mean values of age in each industrial plant.



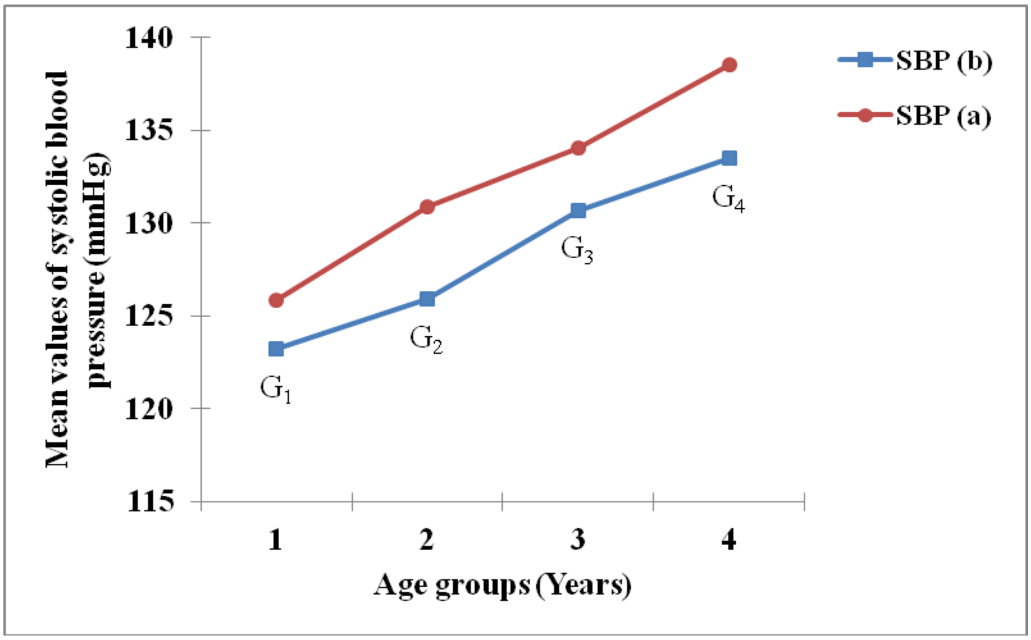
(Fig. 4.18): Means values of diastolic blood pressure (DBP) of subjects by mean values of age in each industrial plant.



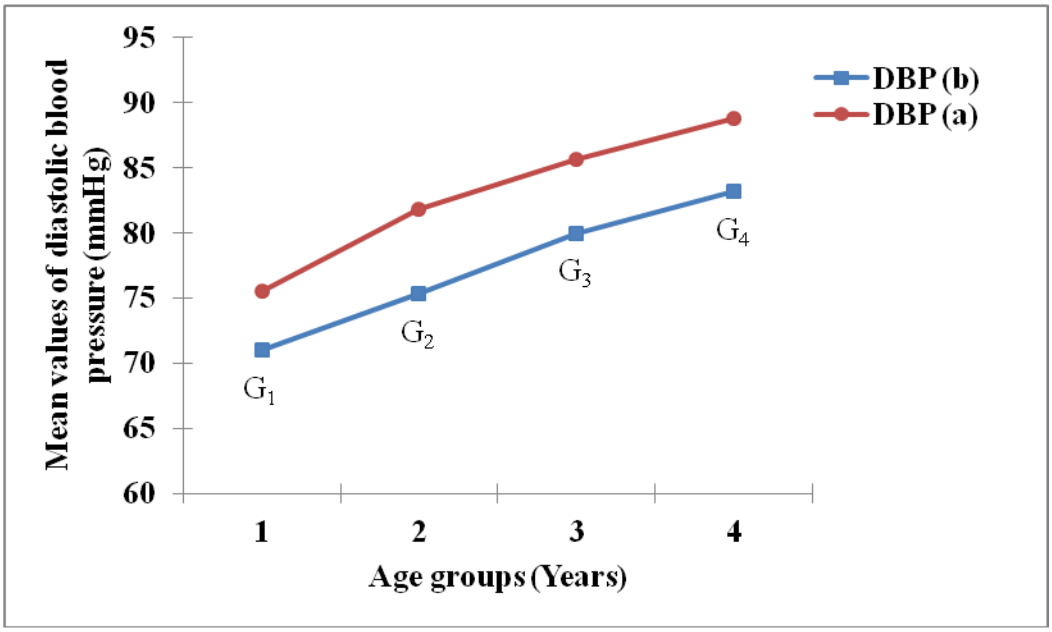
(Fig. 4.19): Means values of blood oxygen saturation (SPO_2%) of all selected workers before and after exposure to noise according to different age groups.
Age groups: G_1: 16-25 yr, G_2: 26-35 yr, G_3: 36-45 yr, G_4: more than 45 yr.



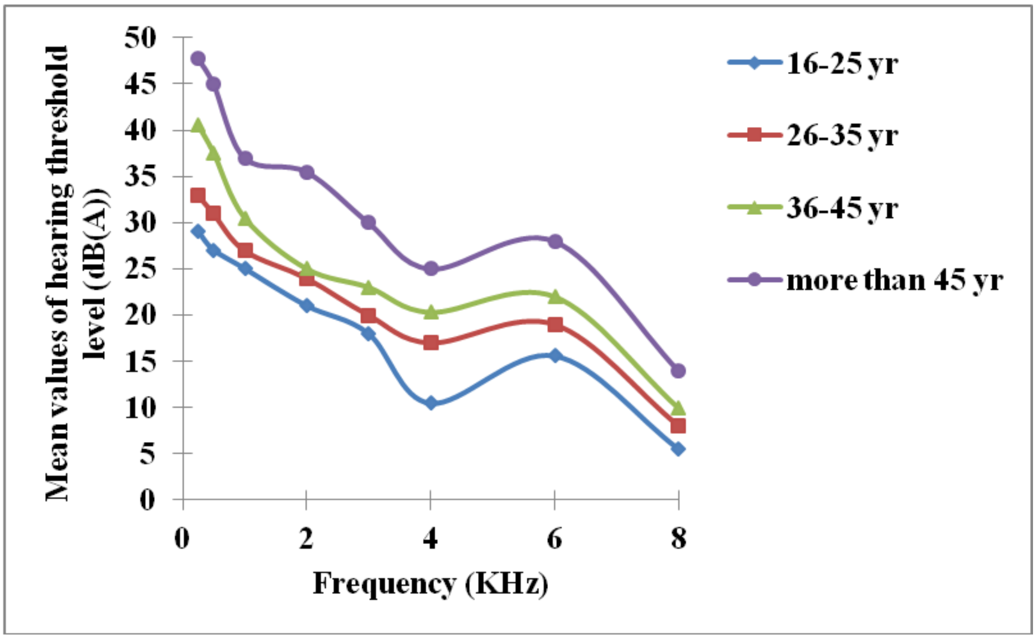
(Fig. 4.20): Means values of Pulse rate (P.R) of all selected workers (before and after exposure to noise according to different age groups.



(Fig. 4.21): Means values of systolic blood pressure (SBP) of all selected workers before and after exposure to noise according to different age groups. Age groups: G_1: 16-25 yr, G_2: 26-35 yr, G_3: 36-45 yr, G_4: more than 45 yr.



(Fig. 4.22): Means values of diastolic blood pressure (DBP) of all selected workers before and after exposure to noise according to different age groups.



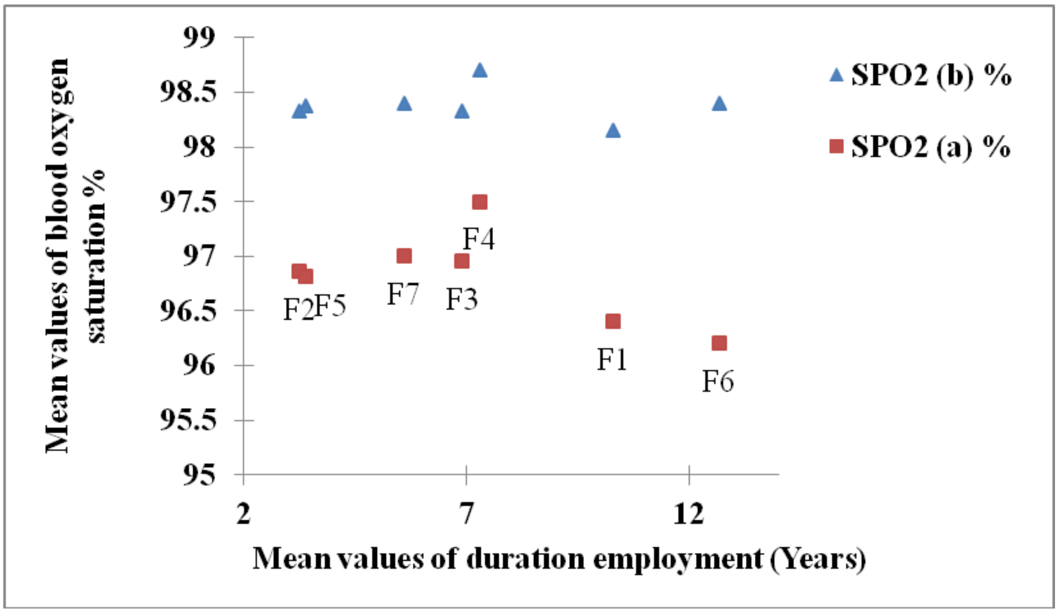
(Fig. 4.23): Mean values of hearing threshold level (HTL) of right ear (R) of workers according to different frequencies by different age groups.
Age groups: 16-25 yr, 26-35 yr, 36-45 yr, and more than 45.

4.4.2 Duration of employment Health Effects Dependence

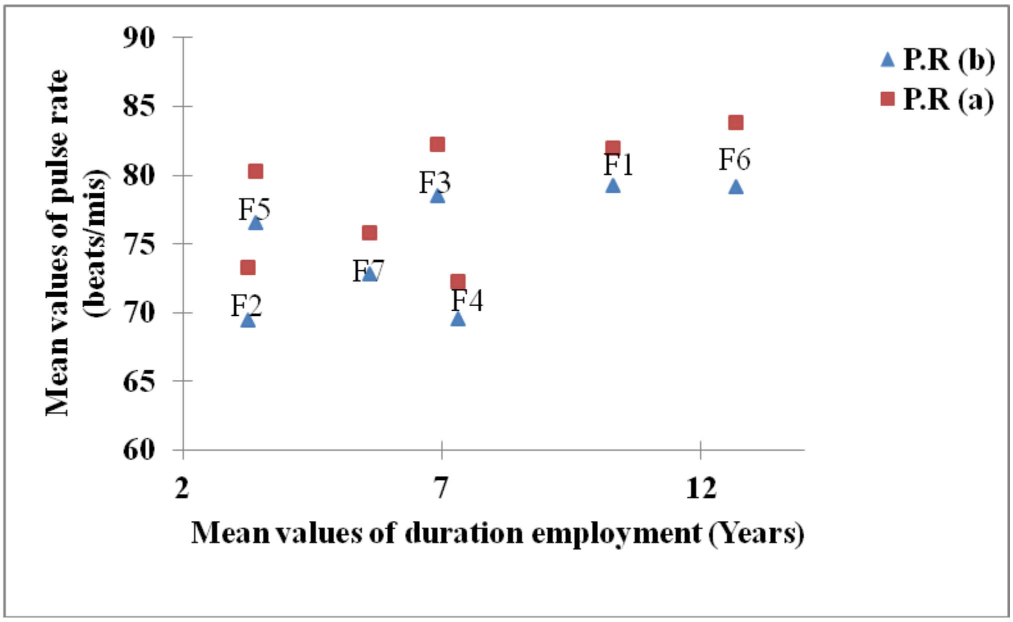
The dependence of the mean values of blood oxygen saturation, pulse rate, arterial blood pressure (systolic and diastolic) on duration of employment of workers in the studied industrial plants is presented in (Figs 4.24-4.27).

It can be observed that there are significant correlation between mean values of blood oxygen saturation, pulse rate, arterial blood pressure (systolic and diastolic), and duration of employment of workers in the studied industrial plants.

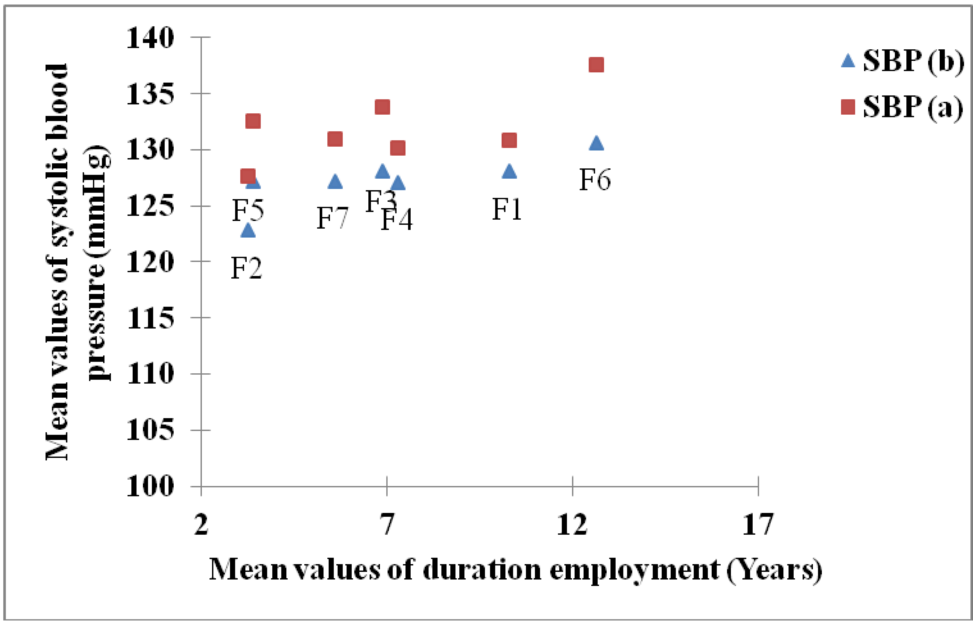
Comparison of the different duration of employment groups showed that the mean values of blood oxygen saturation were lower among the workers with longest duration of employment. While the pulse rate, and the arterial blood pressure (systolic and diastolic), and hearing threshold level were significantly higher among the workers with longest duration of employment (Figs 4.28-4.31), (Fig 4.32).



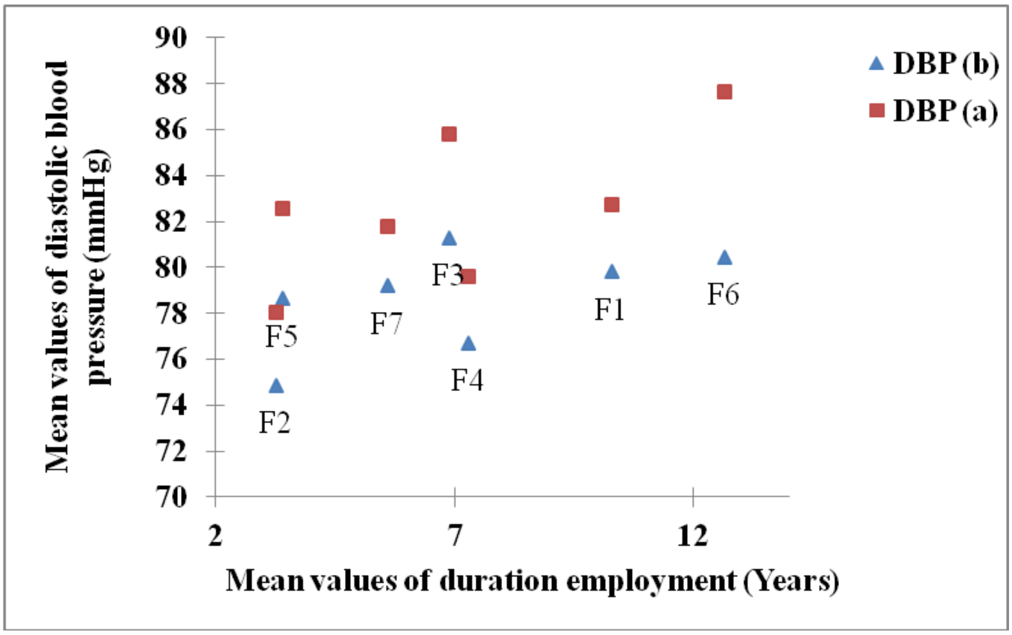
(Fig. 4.24): Means values of blood oxygen saturation (SPO_2%) of workers by mean values of duration of employment in each studied industrial plant.



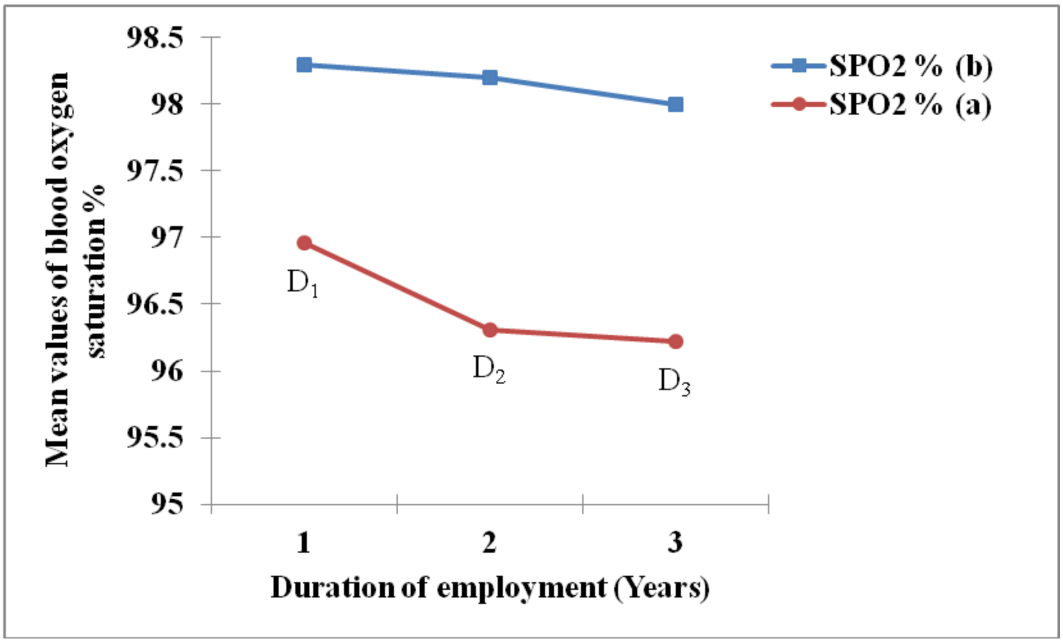
(Fig. 4.25): Means values of pulse rate (P.R) of workers by mean values of duration of employment in each studied industrial plant.



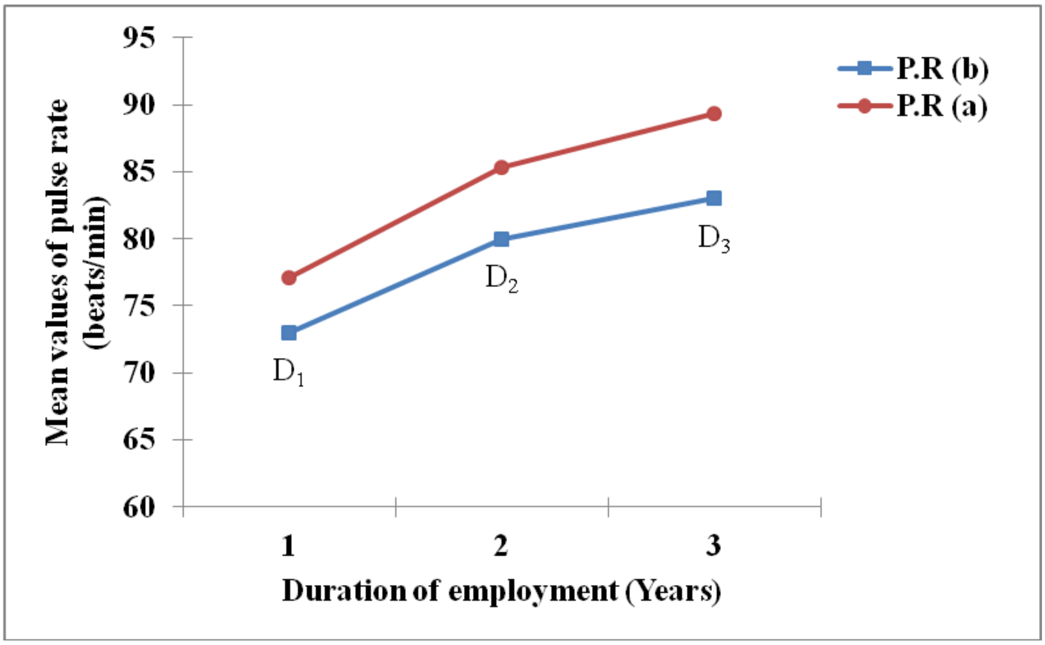
(Fig. 4.26): Means values of systolic blood pressure (SBP) of workers by mean values of duration of employment in each studied industrial plant.



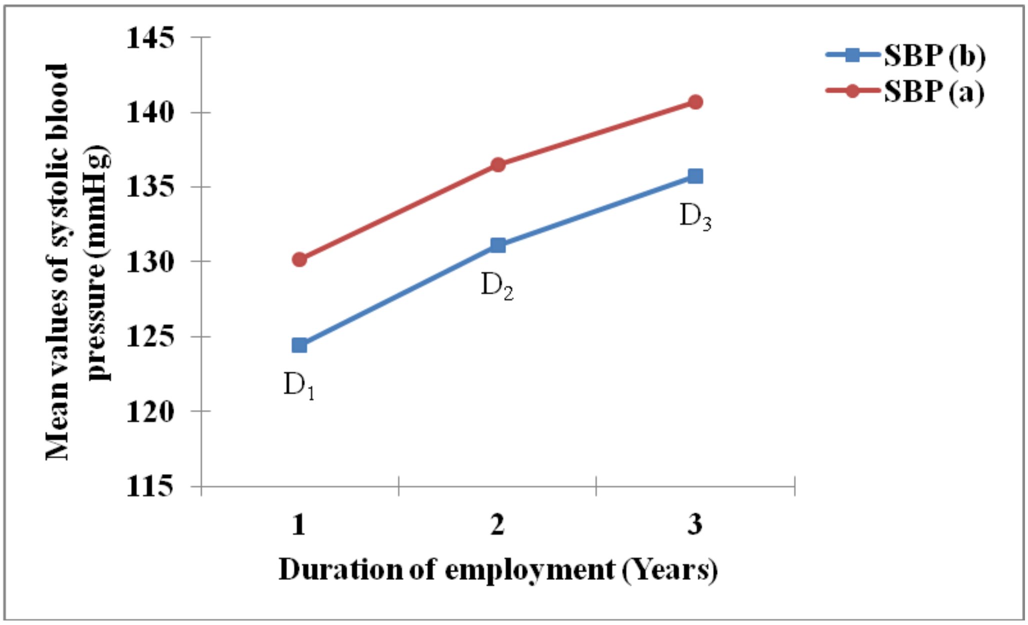
(Fig. 4.27): Means values of diastolic blood pressure (DBP) of workers by mean values of duration of employment in each studied industrial plant.



(Fig. 4.28): Means values of blood oxygen saturation (SPO_2%) of all selected workers before and after exposure to noise according to different duration of employment groups.
Duration of employment groups: D_1: 1-9 yr, D_2: 10-18 yr, D_3: 19-27 yr.

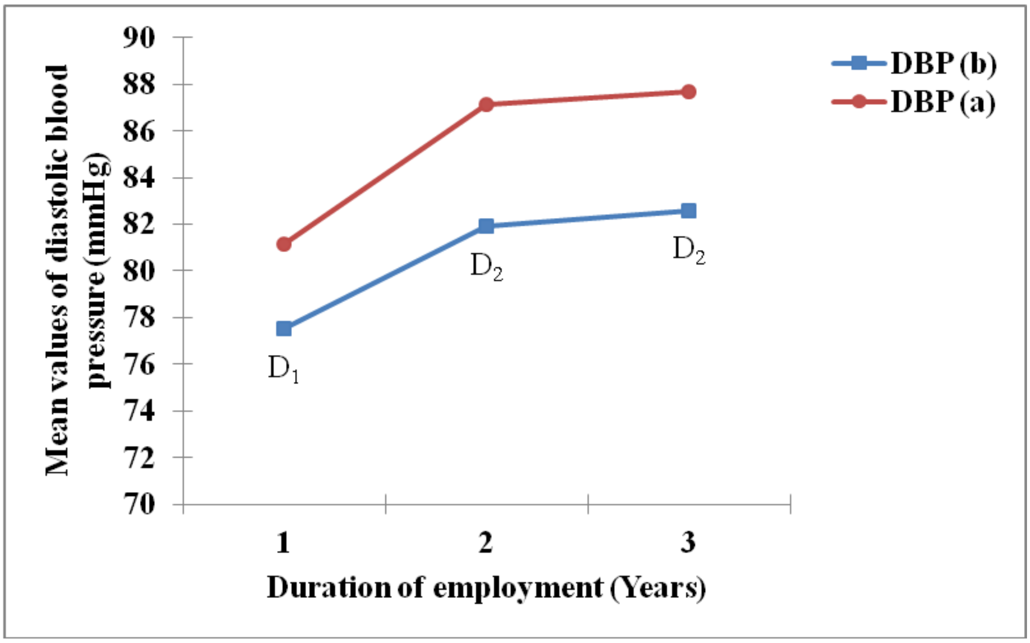


(Fig. 4.29): Means values of pulse rate (P.R) of all selected workers before and after exposure to noise according to different duration of employment groups.

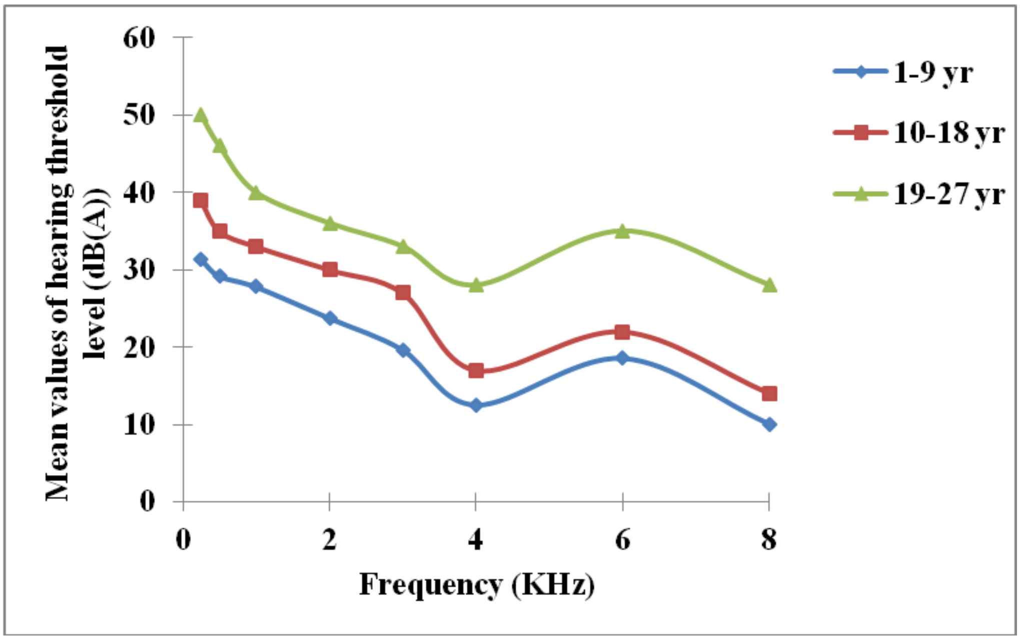


(Fig. 4.30): Means values of systolic blood pressure (SBP) of all selected workers before and after exposure to noise according to different duration of employment groups.

Duration of employment groups: D_1: 1-9 yr, D_2: 10-18 yr, D_3: 19-27 yr.



(Fig. 4.31): Means values of diastolic blood pressure (DBP) of all selected workers before and after exposure to noise according to different duration of employment groups.



(Fig. 4.32): Mean values of hearing threshold level (HTL) of right ear (R) of workers according to different frequencies by different duration of employment groups.

Duration of employment groups: 1-9 yr, 10-17 yr, and 18-25 yr.

Chapter Five
Discussion and Recommendations

5.1 Discussion

An occupational noise exposure study was carried out at various types of seven industrial plants in Jenin city. Equivalent sound pressure levels (SPL)[L_{eq} – values] in all studied plants ranged from 82.5 to 110.5 dB(A), with mean of (94.34 ± 9.69) dB(A) [mean ± SD]. The highest occupational noise level (Table 4.1) was observed at stonecutter with (110.5 dB(A)), and the lowest at Food factory with (82.5 dB(A)).

Five of the seven industrial plants (Haddad Factory, Albareeq Factory, Concrete Factory, Sewing Factory, and the stonecutter) had occupational noise more than 90 dB(A), and two (Food Factory, Carpentry) had occupational noise less than 90 dB(A).The overall results in this study indicated that various groups of workers are exposed to high occupational noise levels.

In this study a hypothesis was set that there is an effect of noise pollution on blood oxygen saturation, pulse rate, arterial blood pressure (systolic and diastolic), and hearing threshold levels of workers in selected industrial plants in Jenin city, which was suggested by other previous studies (Abdel-Ali M. M., 2001, Abdel-Nasser I.S. 2005). The obtained results from measurements and statistical analysis provide a strong convention for the assumed hypotheses.

This study showed that the blood oxygen saturation values before exposure to noise is close for the various groups of workers, and these values are decreased after exposure to occupational noise (Table 4.2). The behaviors of blood oxygen saturation as dependent variable showed continuous decrease with occupational noise levels (Fig 4.11), age (Figs 4.15 &4.19), and the duration of employment (Fig 4.24 & 4.28) as independent variables. The strength of the results is good as can be understood from the Pearson correlation coefficient (0.779) and the Probability (0.039) between sound pressure level (SPL) and blood oxygen saturation (Table 4.10). In addition the Pearson correlation coefficient and the Probability between blood oxygen saturation before and after exposure to noise are 0.714, 0.042, respectively (Table 4.11). However the results of this study are in agreement with other studies which support that exposure to noise leads to decrease in blood oxygen saturation (Short M., 2011, Zahr L.K., 1995, Johnson A.N., 2001).

Most occupational noise studies have focused on the possibility that noise may be a risk factor for cardiovascular diseases. Similarly, this thesis studied the possible effects of noise on pulse rate, arterial blood pressure (systolic and diastolic).

The values of pulse rate and arterial blood pressure (systolic and diastolic) are increased after exposure to occupational noise during work (Table 4.2). The behaviors of the pulse rate and arterial blood pressure (systolic and diastolic) as dependent variables showed a continuous increase with occupational noise levels (Figs 4.12 - 4.14), age (Figs 4.16 - 4.18, Figs 4.20 - 4.4.22), and duration of employment (Figs 4.25 - 4.27, Figs 4.29 - 4.31) as independent variables.

The statistical results for the dependent variables (P.R, SBP, and DBP) showed that Pearson correlation coefficients between sound pressure level and the dependent variables are approximately equal to one, and the Probabilities are

< 0.05. This indicates that there is strong correlation between SPL and the dependent variables (Table 4.10). In addition the Pearson correlation coefficient and the probabilities (Table 4.11) showed that there is significant correlation between the dependent variables before and after exposure to noise.

This study showed that the health effects of noise on human depend on the noise level itself. More specifically, the workers exposed to noise more than 90 dB(A) have stronger health effects compared to those exposed to occupational noise less than 90 dB(A) (Table 4.3).

The net change in dependent variables before and after exposure to noise (Table 4.4) showed that the shift in blood oxygen saturation was 1.64% for factories with SPL more than 90 dB(A) and 1.33% for factories with SPL less than 90 dB(A), while the shift in pulse rate was 3.68 beats/min in the first group of factories, and 2.8 beats/min in the second group. In the case of blood pressure it was observed that the differences in systolic blood pressure in the first and second groups of factories were 5.05mm-Hg, and 3.73 mm-Hg, respectively. On the other hand, the differences in diastolic blood pressure were 4.21mm-Hg in the first group and 3mm-Hg in the second group.

The results of this study are consistent with other finding's studies that found the average rise in systolic blood pressure was 2.462 mm-Hg, while it was 3.06mm-Hg for diastolic blood pressure (Mahmood R., 2007). Another study showed that there is a mean increase of 2.5mm-Hg for both systolic and diastolic blood pressure (Talbortt E.O., 1999). It was found that workers with eight hours average noise exposure of 85 dB(A) had higher blood pressure than workers with workplace average noise exposure of 59 dB(A) (Chan C., 2007). In another study (Powazka,etal.2002) the high exposure workers had significantly increased systolic blood pressure levels with average of 125 mm-Hg, compared with the low exposure with an average of 121 mm-Hg, while the average of diastolic pressures were the same in both groups (80mm-Hg). In the same study it was found that exposure to noise caused a statistically significant increase in pulse rate by average 4.7 beats/minute for workers in noisy factories (Fogari, 2001), in agreement with the result of this study which showed that the shift in pulse rate was 3.39 beats/min for the whole study population.

In this study it is noticed that the effects of noise pollution on blood pressure, and heart rate increase with age are in agreement with the previous result of the study done on people between the ages of (18 – 80 yr) which found that the effects were greatest among the elderly (Rosenlund M, 2001).

There is a positive correlation between different frequencies and sound pressure level (Table 4.10). Significant correlations were found between percentage of several degrees of hearing impairment in both ears of subjects and occupational noise levels according to (OSHA, NIOSH & ASHA, and EPA's definition). It can be observed that there are significant hearing threshold shifts in right and left ears of subjects before exposure to occupational noise and after 6 hours from the beginning of morning shift (Figs 4.4 - 4.10).

It may be concluded that the age and duration of employment are important factors in the developing of hearing impairment (Figs 4.23&4.32).

The findings of other studies support the hearing results of this thesis that showed the relationship between developing of hearing impairment and continuous exposure to noise (Joshi S. K., 2003, Rabinowitz, P., 2000, WHO, 2001).

In sewing factory the selected workers contain both genders; 10 males, and 19 females. It is observed that the net change in blood oxygen saturation was 1.8 % for males and 1.42 % for females, while the net change in pulse rate for males and females was 3.9 beats/min, 3.69 beats/min, respectively. The shift in systolic blood pressure was 6 mm-Hg for male and 4.9 mm-Hg for female. But in the case of diastolic blood pressure the net change was 4.6 mm-Hg for male, and 3.53 mm-Hg for females (Table 4.5). The results indicate that males are more affected by noise compared to females; this might be due to smoking, about 80% of the males workers in this factory are smokers. Which has an important reason in decrease the blood oxygen saturation, and elevating the blood pressure and the pulse rate.

Contrary, the hearing threshold results showed that females are more affected by noise compared to males. The percentage of degrees of hearing impairment according to (OSHA, NIOSH & ASHA, and EPA) is larger in females as can be shown in (Tables 4.7, 4.8 and 4.9). The possible reason for that difference is the amount of noise in female working room is larger than in male room, and this is due to very addition insensitive sound comes from music.

5.2 Recommendations

The following are some recommendations which can be carried on to reduce the occupational noise levels and their health hazardous on workers health:

1- Control of noise at the source. Therefore, it is first necessary to determine the cause of the noise and then to decide on what can be done to reduce it. In this study, for example in sewing factory much noise comes from music more than machines especially in female department, so the first step to reduce sound in this factory is lowering the sound comes from high music, or stopping it.
2- Allowing enough spaces between machines.
3- Shielding the emitting noise by acoustic barrier to help in absorbing or deflecting noise.
4- Provide workers with noise protective equipment like ear protection.
5- There must be supervision from ministry of work in order to put lows concern with noise health effects and work safety.
6- Regular maintenance for noisy machines or buying less noisy equipments.
7- Reduce the worker’s time exposure to noise.
8- Not to operate all machines at the same time especially at stonecutter.
9- Periodic tests for the workers in order to determine the health effects of noise early.
10- Building the noisy factories away from the residential areas.

11- Factories designer has to come up with designs that increase the area of factories.

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جامعة النجاح الوطنية

كلية الدراسات العليا

التأثيرات الصحية للضوضاء ذات المستوى dB(A) (110 - 90)
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قدمت هذه الأطروحة استكمالا لمتطلبات درجة الماجستير في الفيزياء بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس- فلسطين

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الملخص

ألقت هذه الدراسة الضوء على تأثير الضوضاء على عدد من المتغيرات مثل تركيز الأكسجين في الدم ونبض القلب و ضغط الدم (الانقباضي والانبساطي) ودرجة السمع. تم اختيار 115 عاملا (96 ذكر و 19 أنثى) كعينة عشوائية من أجل تحقيق الهدف المنشود. حيث كانت معدل أعمارهم 35.22 سنة، ومعدل مكوثهم في العمل الحالي 6.99 سنة.

لقد تم أخذ هذه العينة من العمال من سبعة مصانع مختلفة الأنواع في مدينة جنين، حيث بلغ مستوى الضوضاء في هذه المصانع (82.5 - 110.5) ديسيبل بمعدل 94.34 ديسبل. وقد تم أخذ عدد من القياسات ذات العلاقة بتركيز الأكسجين في الدم ونبض القلب وضغط الدم (الانقباضي والانبساطي) ودرجة السمع، قبل التعرض للضوضاء وبعد 6 ساعات من التعرض للضوضاء، وقد وجد أن هناك علاقة قوية بين مستوى الضوضاء وكل من تركيز الأكسجين في الدم ونبض القلب و ضغط الدم (الانقباضي و الانبساطي) ودرجة السمع. حيث كان معامل ارتباط بيرسون بين المتغيرات ومستوى الضوضاء تقريبا 1 والاحتمالية < 0.05 ، فعلى سبيل المثال كان معامل ارتباط بيرسون بين مستوى الضوضاء وتركيز الأكسجين في الدم (0.779)، والاحتمالية (0.039). بينما كان معامل ارتباط بيرسون لنبض القلب (0.790) والاحتمالية (0.035)، وبالنسبة لضغط الدم الانقباضي وجد أن معامل ارتباط بيرسون كان (0.734) والاحتمالية كانت (0.030)، بالاضافة كان معامل ارتباط بيرسون لضغط الدم الانبساطي

(0.795) والاحتمالية (0.033)، بينما تراوحت قيم بيرسون لدرجة السمع عند مختلف الترددات من0.626 إلى 0.954.

أظهرت هذه الدراسة أن تأثيرات الضوضاء على الجوانب الصحية تعتمد على مستوى الضوضاء بحد ذاته، وبشكل أكثر تحديدا، وجد أن العمال الذين يتعرضون لضوضاء أعلى من 90 ديسبل لديهم تغير في قيم تركيز الأكسجين في الدم ونبض القلب وضغط الدم (الانقباضي والانبساطي) ودرجة السمع، بشكل أكبر من العمال الذين يتعرضون لضوضاء أقل من 90 ديسبل.