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Noise Pollution in Factories in Nablus City

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Dedication

This Thesis is dedicated to my parents, brother, sisters, and my wife Banan.

With Love and Respect.

Acknowledgement

I am very grateful to my supervisors, Dr. Issam Rashid and Dr. Zaid Qamheih, for their efforts and guidance throughout the entire research.

Special thanks are addressed to the owners of the factories for their help.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ANOVA	Analysis of variance
C_n	Actual exposure time (in hours)
D	Noise dose
dB	Decibel(unit of sound level using a logarithmic scale)
dB(A)	Decibel, by the A-weighted
dB(B)	Decibel, by the B-weighted
dB(C)	Decibel, by the C-weighted
dB(D)	Decibel, by the D-weighted
EPA	Environmental Protection Agency
Hz	Hertz (unit of frequencies)
ISO	International Standards Organization
L	The steady state noise level in dB (A)
L_{10}	Noise levels exceed 10% of time
L_{50}	Noise levels exceed 50% of time
L_{90}	Noise levels exceed 90% of time
L_{dn}	Day-night Sound level
L_{eq}	The equivalent noise level
L_N	Noise levels exceed N% of time
L_{NP}	Noise pollution level
L_p	Sound pressure level

L_w	Sound power level
OSHA	The Occupational Safety and Health Act
Pa	Pascal (unit of pressure)
P	Pressure
P_0	Chosen reference pressure
rms	root mean square
S	Significant
T_n	The permitted exposure time (in hours)
W	Power
W_0	Chosen reference power

Abstract

Noise pollution is getting more and more important issue, especially in the industrialized and developed countries. Industrial noise is a serious environmental problem, which annoys us and disrupts our daily activities. In West Bank, however, there are so far no regulatory laws to limit high industrial noise level. Due to general unawareness about the ill effects of high noise levels, the owners of factories pay negligible attention to provide safety measures to their workers.

Accordingly, this study is concerned in measuring the equivalent noise levels L_{eq} in 38 factories in Nablus City, then comparing them with the international standards of noise. The obtained mean-value of these levels is 85.5 dB(A). 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 the workers. The continuous exposure of the workers to such high noise levels can cause hearing damage, speech masking and annoyance. High-level noise not only hinders communication between workers, but, depending upon the level, quality, and exposure duration of the noise, it may also result in different type of physical, physiological and psychological effects on the workers.

This study suggests some recommendations and advice -for the workers in the factories, owners of the factories and for the Palestinian authorities- to relieve the noise pollution problem in factories in Nablus City.

Chapter 1
Introduction

1.1. Previous studies on noise

Study of noise pollution and its effects on human being is an increasingly expanding topic in the world. Many noise studies were conducted to investigate the magnitude of the problem in various cities throughout the world.

A general study of noise pollution carried out recently in the community of Valencia (Spain) which has revealed that environmental noise is a significant problem in most cities of Spain. (Amando Garcia, 1997).

According to an EPA report in the USA, it is suggested that the equivalent noise level (L_{eq}) for 24 hours should be kept below 70 dB(A) (decibel by A-weighted) over a 40 years working life to protect against damage to hearing. (Zheng D. *etal.* 1996).

A study of "Putting a lid on factory noise" has showed that three kinds of industrial noise are characterized for determining exposure: constant noise levels, varying noise levels and noise pulses. (John, *etal.*1994).

In Italy, the study on "Noise risk caused by machines in food plants" has showed that noise levels inside processing industries are still so high to make considerable risk of ear-illness for workers. (Biondi P.*etal.* 1996).

A study of "Occupational noise exposure limits for developing countries" in Pakistan has revealed that there is a criterion for steady noise of [L_{eq} = 88 dB(A)] for 8 hours a day and 6 days a week with halving rate of 3dB(A) and overriding limit of 115 dB(A). (Shaikh G.1998).

A study of "Noise emission levels in cool industry" in Britain has revealed that cool industry has higher noise levels than the established limits for occupational noise exposure. (Sharma O. *etal.* 1998).

The problem of noise has been studied in Arraba in Palestine, the obtained noise levels are higher than the adopted international standards, so Arraba town is considered unacceptable area.(Abdel-Raziq, *etal.* 2000).

A special questionnaire based on the ideas and temperament of common people, was applied as a noise survey in Palestine in 1998, it was based on the exposure to noise in a household environment. It was revealed that 69.4% of households in West Bank and 62.8 % in Gaza Strip were seldomly exposed to noise. The percentages of households that were sometimes exposed to noise were 14.3 % in West Bank, and 18.5 % in Gaza Strip, whereas 16.9 % of households in the Palestinians were very often exposed to noise. This survey also showed that 54.2 % of the residents in the Palestinian cities felt that road traffic was the most important source of noise. Additionally, 24.7 % of households in West Bank and 44 % in Gaza Strip considered that construction work was the most important source of noise. (Palestinian Central Bureau of Statistics, 1998).

1.2. Objective of this study

No regulations of noise pollution have been yet formulated in Palestine. In the West Bank, noise pollution data and its effects are lacking. Therefore, the aim of this study is to investigate the noise pollution practices by measuring the equivalent noise levels in a large sample of factories in Nablus City. The measured L_{eq} values will be compared with the standard scales of noise to classify the selected factories according to noise level and noise dose. Additionally, this study suggests some recommendations and advice for the workers in the factories, owners of the factories and Palestinian authorities.

1.3. Description of noise and its sources in Nablus City

Sound may be described as a propagating disturbance through a physical medium. It is perceived by the ear as pressure wave superimposed upon the ambient air pressure at the listener. The sound, which is unwanted by the recipient, is defined as noise. In the industrial sense, noise usually means excessive sound or harmful sound. The major sources of noise are: surface transportation, recreational vehicles, air transportation, construction / industrial equipment, and household appliances. In industrial environments, noise sources exist both inside and outside the plant buildings. Various types of processing and production machinery may be found inside, and machines such as motors, fans, cooling towers, and so on, may be located outside.

Noise pollution in Palestine cities and towns is increasingly becoming more evident because of the increasing number of noise sources as: machines, markets, vehicles and factories.

In Nablus City, there are some specific issues affecting the noise level. These are: the shortage of open spaces, the heavy road traffic as a consequence of narrow streets, the refugee camps that are not subjected to regulations and health laws, and the factories that emit daily high noise.

Factory noise is an important health problem in the city of Nablus, because the factory owners do not limit the high noise levels emitting from the machines. However, the workers are exposed to high noise levels daily, the owners of factories neglect using absorptive materials to protect workers from such high noise levels.

According to that, noise studies are getting more and more popular because of their importance in human life. This study is concerned in the industrial noise emitted from the factories in Nablus City. So, our goal is to investigate the noise pollution practice by measuring the equivalent noise levels inside the factories.

The actual annoyance caused by industry in the environment is dependent upon many factors such as: magnitude of noise, background noise level, the character of the noise source (i.e., broad band or a pure tone, steady or intermittent), the working hours, the land use of the affected area such as: recreational, residential or commercial and the presence of other noise sources in the area.

1.4. Effects of noise pollution on people

Excessive noise is dangerous and a health hazard, since it has been blamed for hearing damage, community annoyance, hypertension, fatigue and heart trouble.

Most researchers in the USA feel that the deleterious effects of noise are confined to damage of the hearing mechanism and to mask of auditory information (Lord, *etal.* 1980). Hearing damage, speech masking, and annoyance are the best-documented effects of noise on human beings. The hearing mechanism is divided into three parts; the outer ear, middle ear and the inner ear. The outer and middle ear joining together to collect the sound waves and transform the acoustic energy into mechanical energy. The inner ear transduces this mechanical energy into a series of nerve impulses which represent the acoustic events.

The main physiological effect of noise is that the inner ear may be damaged due to sounds of very high intensity range, such as explosions. The damage may be caused gradually as a result of long exposure to high industrial noise level range.

Other noise pollution effects observed in humans include changes in the electrical activity of the brain, heart and respiration rate, gross motor activity, changes in the size of several of the glands of endocrine system, blood pressure changes, constriction of the blood vessels, dilation of the pupil of the eye, and observations of irritability, nausea, fatigue, anxiety, and insomnia. A part from these physical changes, noise can cause psychological disturbances. Interruption of sleep by noise can cause people to become irritable and resentful against the cause of noise (Webb, 1978). Therefore, noise affects the hearing function of the ear in two ways: (1) It may cause permanent physical damage to the hearing mechanism, rendering it insensitive to important components of sound. (2) It may mask or drown out desirable sound.

Briefly, it can be said that noise can be the cause of hearing loss, mental illness, reduction in productivity, or even loss of life.

Chapter 2
Mathematical Treatment of Noise Pollution

2.1. Theoretical background

The Decibel (dB) is used in environmental noise pollution as a measure of sound power level, sound intensity level and sound pressure level. This leads us to use a logarithmic rather than a linear scale, the logarithmic unit is further justified because it compresses the tremendous range of audible sound pressures to a convenient scale. So, this is a simple method of allowing us to do our calculations within the scale of small numbers rather than an extremely large scale of numbers. Level indicates the logarithmic ratio of power, intensity, pressure to a related reference quantities. The decibel is defined as 10 times the logarithmic (base 10) of this ratio. The argument of the logarithm is dimensionless and the scale is used to give the level of the sound in decibels.

Sound power of a source is the total sound energy radiated by the source per unit of time. The decibel for sound power level is

$$L_w = 10 \log (w/w_o) \text{ dB} \qquad (1.1)$$

where,

w: sound power of a source (watt)

w_o: chosen reference power = 10^{-12} watt

Sound intensity in a specified direction is the sound energy transmitted in that direction through a unit area in a unit of time. The decibel for sound intensity level is

$$L_I = 10 \log (I/I_0) \text{ dB} \qquad (1.2)$$

where,

I: sound intensity (watt/ m^2)

I_0: chosen reference intensity = 10^{-12} (watt/ m^2)

At present there are no instruments that can directly read either sound power level or sound intensity level. The human ear and microphones respond to sound pressure, and most acoustical instruments are calibrated to measure the sound pressure level. The decibel for sound pressure level is the most common decibel scale since the sound pressure squared is proportional to the sound intensity and it is given as:

$$L_p = 10 \log (P^2/P_o^2) \text{ dB} \qquad (1.3)$$

where,

P: sound pressure (pa)

P_o: chosen reference pressure = 2×10^{-5} pa.

The chosen reference P_0 is often referred to as the threshold of hearing at 1000 Hz. The threshold of hearing for binaural listening is the sound pressure in a free field and it is a function of frequency. (Webb, 1978).

The indices or quantities will be used to describe the noise pollution are: L_{eq}, L_{NP}, L_{10}, L_{50}, L_{90} and L_N, where:

L_{eq}: the equivalent continuous sound level in dB(A).

L_{NP}: the noise pollution level.

L_N: the noise levels exceeded N% of time.

L_{10}, L_{50} and L_{90} represent noise levels exceeded 10%, 50% and 90% of time, respectively. These quantities can be measured by sound level meter. The descriptor for range of noise variation is L_N. For example, L_{90} is used to estimate the residual noise level in the environment. L_N levels are derived from statistical distribution analyzers which compute the probability of noise level exceeding each of a series of amplitude threshold. L_{eq} and L_N values are used to evaluate existing noise. For example, Noise pollution level, L_{Np}, can be approximated by the formula:

$$L_{Np} = L_{eq} + (L_{10} - L_{90}) \qquad (1.4a)$$

where,

L_{eq} : the equivalent noise level

$(L_{10} - L_{90})$: represents a penalty annoyance caused by fluctuations in noise level.(Irwin J. *et al.* 1979).

In this study, the L_{eq}- values will be measured, then analyzed to decide whether these values are within the standard noise levels or not. The L_{eq} can be calculated using the equation:

$$L_{eq} \approx L_{50} + (L_{10}-L_{90})^2 / 60 \qquad (1.4b)$$

2.2. Standards of noise

In Britain, the only relevant standard applying to internal noise is the Code of Practice in 1972. This is intended primarily for factory noise to reduce the exposure of employed persons to noise, and gives a recommended limit of 90 dB (A) for an eight hour working day which is designed to avoid hearing damage. The system adopted of L_{eq} meant the higher levels of exposure for shorter times could be accepted, e.g.

90 dB (A) for 8 hours total.

93 dB (A) for 4 hours total.

96 dB (A) for 2 hours total.

and so on up to:

108 dB (A) for 7.5 minutes total.

The Occupational Safety and Health Act (OSHA) Noise standards of the United States are designed to protect workers exposed to hazardous noise environmental from incurring permanent hearing loss. The OSHA was enacted to ensure that the workers have safe and healthful working conditions, then OSHA extended the applicability of the requirement of the standard to all workers engaged in interstate commerce. The regulation does basically two things: It sets maximum level of industrial noise to which an employee may be exposed, and it indicates what action the employer must take if these levels are exceeded. According to OSHA, the action required by the employers can be summarized in three steps:

1- When employees are exposed to sound exceeding permissible levels, feasible administrative or engineering control shall be utilized.

2- If such controls fail to reduce sound levels to within the allowed limits, personal protective equipment shall be provided.

3- An effective hearing conservation program shall be administered for as long as the noise levels exceed those permitted by law. (Webb, 1978).

OSHA standard sets a maximum permissible noise level of L_{eq} = 90 dB(A), measured on the slow meter, for 8 hours work – day. OSHA permissible noise exposures are given in Table (2.1).

Table (2.1): OSHA (1970) – scale

Time permitted per day (hr)	Noise level dB (A)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

The table indicates the duration of exposure to higher sound intensities which will result in no more damage to hearing that produced by 8 hours at 90 dB(A). In addition, the table shows that employees must not be exposed to steady sound levels above 115 dB(A). It was also observed that for each increase in noise level of 5 dB(A), the permitted exposure time is halved.

The proposed OSHA noise regulations (Fedral Register, 1974) are used to establish requirements and procedures that will minimize the risk of pertinent hearing impairment from exposure to hazardous levels of noise in workplaces. (Harris,1979).

Any employee exposed to 8 hours time-weighted average of 85 dB (A) or above should be identified and his exposure measured and recorded. The important change which will occur if the proposed standard is adopted is Table (2.1) will be replaced by Table (2.2).

There are two cases of steady state noise that describe the permissible exposure limits.

1- Steady state noise-single level:

The permissible exposure to continuous noise must not exceed an eight hour time-weighted average of 90 dB(A) with a doubling rate of 5 dB(A). Some of permissible times are calculated using equation (1.5), as shown in Table (2.2).

Table (2.2): Proposed OSHA(1974)-scale

Noise level L [dB(A)]	**Time permitted T (hr)**	**Noise level L [dB (A)]**	**Time permitted T (hr)**
85	16.0	101	1.73
86	13.93	102	1.52
87	12.13	103	1.32
88	10.57	104	1.15
89	9.18	105	1.0
90	8.0	106	0.87
91	6.97	107	0.77
92	6.07	108	0.67
93	5.28	109	0.57
94	4.6	110	0.5
95	4.0	111	0.43
96	3.48	112	0.38
97	3.03	113	0.33
98	2.83	114	0.28
100	2.0	115	0.25

The permissible exposure to continuous noise level must not exceed a permitted time T (in hours) computed by the empirical equation:

$$T = 16 \times 2^{[-0.2(L-85)]} \qquad (1.5)$$

Where , L is the steady state noise level in dB(A).(Harris, 1979).

The quantity T is plotted in Fig. (2.1) for different steady state noise levels. At higher noise levels, the permitted times decrease with noise level as shown in the figure.

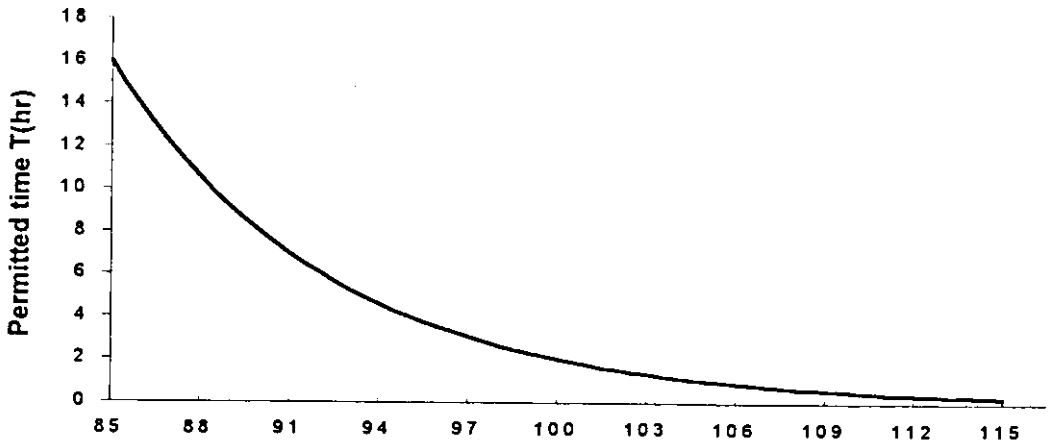

Fig. (2.1): Permitted time for different noise levels

2- Steady state noise –two or more levels:

When the noise levels at the work site are known to change very little during the day, and when the time spent by the worker at each work site is clearly defined, simple sound level meter readings will suffice to establish employee exposure. Employee exposure to continuous noise at two or more levels should be computed in terms of [fraction of permissible] daily noise dose (D), which is defined by the equation:

$$D = C_1 / T_1 + C_2 / T_2 + C_3 / T_3 + \ldots\ldots + C_n / T_n \qquad (1.6)$$

where,

C_n is the total actual exposure time (in hours) at a specified noise level.

T_n is the total permitted exposure time (in hours) at that level.

If D exceeds unity, then, the mixed exposure should be considered to exceed the limit value. Therefore, OSHA noise regulation requires that a worker's daily noise dose be less than unity. (Irwin J. *etal.*1979).

Chapter 3
Experimental Technique

3.1. Methodology

Noise level measurements L_{eq} values were carried out in 38 factories spread through the city of Nablus in between residential, commercial, and industrial areas. The factories have been classified into 7 categories based on products such as: chemical, plastic, food, paper and wood, metal, concrete production, and stonecutter. The factories within each type of industry were selected randomly making sure that both large and small factories were included. Some large factories were physically divided into more than one factory zones e.g., a factory may have 3 different buildings. In such cases, each factory zone was treated separately.

The variations of noise level are consistent with all working hours. So, we choose the duration of the measurement periods to be 3 hours. Each measurement was carried out twice during working days of the week. The first time was during (10:00 to 11:30 A.M), and the second time was during (12:30 to 14:00 P.M) under ideal meteorological conditions, from May 1999 to September 1999. No significant problems occurred during the measurements and observations. The measurements as L_{eq} , L_{dn} , L_5 , L_{10} , L_{50} , L_{90} are read directly by sound level meter by A-weighting, and so the noise pollution level can be calculated easily. These measurements were taken inside the factories (indoor), and the sound level meter was placed in the gathering place of workers. The obtained results were compared with the standard scales to ensure whether or not the sample of factories satisfy the standards. The measurements were analyzed statistically by using the SPSS program to obtain global picture about the noise pollution practices at the factories. Many statistic measures could be known. Analysis of variance (ANOVA) test was used in this study to detect associations between noise level and the dependent variables. The significant (S<0.01) was considered statistically.

3.2. Instrumentation

One of the most useful and important instruments in the analysis of noise is the sound level meter. The noise levels were measured using the Quest model 2900, type 2, integrating and logging sound level meter. The accuracy of such instruments is ±0.5 dB (A) at 25 °C and its precision is 0.1 dB(A). This device amplifies the very small output signal received from the installed microphone and makes it available for processing and for visual display by a readout meter contained within the unit. The basic elements of a typical sound level meter as shown in Fig. (3.1) are:

1- microphone 2- preamplifier 3- special weighting networks

4- amplifier 5- rectifier 6- output 7- scale meter. (Harris,1979).

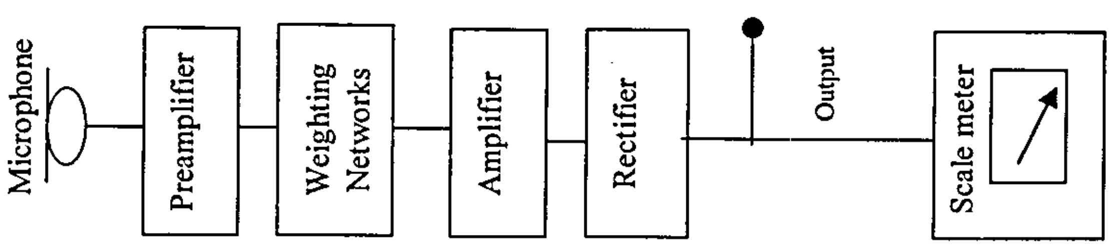

Figure (3.1): Block diagram of a sound level meter

The microphone is transducer which transforms pressure variations in air to a corresponding electric signal. Since the electrical signal generated by the microphone is relatively small in magnitude, a preamplifier is needed to boost the signal before it is analyzed, measured, or displayed. The special weighting networks are used to shape the signal spectrum in much the same way that the human ear responds to sounds of different amplitudes. The "weighted" signal then passes through a second (output) amplifier into a meter. The electrical signal is converted from alternating current to direct current by the rectifier.

The meter and the associated circuitry detect the approximate (rms) value of the signal and display it on a logarithmic scale, laid out to show the signal level in decibels. Three weighting networks, denoted A,B and C, are commonly incorporated in most sound level meters. These networks were designed to provide a response that approximates the way in which the human ear responds to the loudness of pure tones. The B-weighting approximates the loudness curves at medium sound pressure level. The C scale is essentially linear over the frequency range of greatest interest. It approximates the loudness curves at high sound pressure level. The A-weighted sound level has found much use in noise evaluation, since it correlates reasonably well with hearing-damage risk in industry and with subjective annoyance for a wide category of industrial, transportation, and community noises. The A-networks approximates the loudness curves at low sound pressure level. So, our study uses the A-scale that specified in A-weighted sound levels in the OSHA standards.

In addition, a D-weighting network is used for aircraft noise measurements and it is found on some sound level meters. (Lord, *et al.* 1980).

Chapter 4
Results and Discussion

4.1. Experimental measurements

This work presents the main results obtained in a study of noise carried out in factories of Nablus City. These factories are located inside residential, commercial, agricultural and industrial zones. The design of these factories did not follow any kind of regulations and health laws in order to reduce noise pollution. Therefore, this study suggests many recommendations to avoid the workers from high noise levels.

The locations of the factories, the number of workers, and the working hours in each factory are given in Table (4.1). This table shows that 1144 workers are working in the sample of factories at different locations. It was observed that about 68% of workers are doing longer than 8 hours a day, so they are exposed to continuously daily noise. It should be also observed that nine factories are located in residential regions, they give noise to these regions and so influence the life of residents.

The L_{eq}-values were measured in 38 factories in Nablus area. Table (4.2) presents the data for each factory in all categories, all values are ordered ascendly in each category. These values are average values of continuously L_{eq}-values that were registered at every minute by sound level-meter, and were taken three hours individually. This table shows that the values of L_{eq} are different in the same type of factories, because the factories are classified into 7 categories according to the product only. The reasons for different values in the same category are concerned with number of machines, there sizes, how noisy they are and the distance between the machines.

Table (4.1): Categories of factories in Nablus City

Categories of factories	No.	Name of factory	Location	No. of workers	Working hours
Chemical	1	Al- Rajih	Residential	15	8
	2	Painting (Al-Arabia Factory)	Residential	18	8
Plastic	1	Al- Aqad Comp. (machines)	Industrial	90	10
	2	Al – Tebey	Industrial	8	8
	3	Al- Aqad Comp. (washers)	Industrial	80	10
	4	Al- Andalus	Industrial	9	12
	5	Plastic	Industrial	10	8
	6	Malheas	Industrial	220	16
	7	Al- Aqad Comp. (motors)	Industrial	10	10
Food	1	Shalhoop roaster	Residential	6	9
	2	Al- Deak	Industrial	6	8
	3	Qamhiya Tahina	Ind .+Res.	8	8
	4	Al- Zahraa	Industrial	30	8
	5	Plaza	Industrial	6	8
	6	Al – Sanable	Industrial	14	8
	7	Al- Araz ice cream	Res.+Comm.	120	24
	8	Tammam Tahina	Ind .+Res.	8	8
Paper and wood	1	Al- Eqtesad printery	Commercial	8	8
	2	Al – Horriya printery	Commercial	4	8
	3	Al- Zaglol	Industrial	7	20
	4	Al – Nasir	Industrial	125	13
	5	Al- Wafaa	Industrial	35	8
	6	Al – Najah printery	Commercial	8	8
	7	Carton	Industrial	60	13
	8	Hawash Comp.	Industrial	10	8
Metal	1	Nickel and Golvan	Ind.+Comm.	5	8
	2	Aluminum	Agricultural	50	10
	3	Glass	Ind .+Res.	18	8
	4	Cans	Industrial	40	9
Concrete Production	1	Al – Ekhaa flags	Industrial	14	9
	2	Concrete prod. Comp.	Industrial	40	14
	3	Production comp. for flags	Agricultural	15	8
	4	Production comp. for bricks	Agricultural	15	8
Stonecutter	1	Al – Khayat	Industrial	5	8
	2	Al – Foriki	Ind.+Res.	5	9
	3	Al- Aghbar	Industrial	4	8
	4	Sbeah	Ind.+Res.	6	8
	5	Al – Sakhel	Industrial	12	8

Table (4.2): Equivalent sound level values (L_{eq})measured in 38 factories

Categories of factories	No.	Name of factory	L_{eq}(dBA)
Chemical	1	Al-Rajih factory(detergents)	69.7
	2	Painting factory	76.8
Plastic	1	Al-Aqad company(sewing machine)	63.9
	2	Al-Tebey factory (spong)	72.2
	3	Al-Aqad company(washers)	80.8
	4	Al-Andalus factories(Nylon)	86.6
	5	Plastic factory	87.8
	6	Malheas factory(Shoes)	88.1
	7	Al-Aqad company(motors)	96.3
Food	1	Shalhoop roaster	81.2
	2	Al-Deak factory(Fodder)	82.6
	3	Qamhiya Tahina factory	84.1
	4	Al-Zahraa factory(Juice)	84.4
	5	Plaza factory	85
	6	Al-Sanabel factory (Meat)	85.3
	7	Al-Araz ice cream	90.4
	8	Tammam Tahina factory	91.9
Paper and wood	1	Al-Eqtesad Printery	79.7
	2	Al-Horriya Printery	83.6
	3	Al-Zaglol factory	83.7
	4	Al-Nasir factory	84.7
	5	Al-Wafaa factory	85.9
	6	Al-Najah Printery	86.4
	7	Carton factory	92
	8	Hawash Company(Wood)	92.5
Metal	1	Nickel and Golvan factory	83.9
	2	Aluminum factory	84.5
	3	Glass factory	88.3
	4	Cans factory	89.7
Concrete production	1	Al-Ekhaa flags factory	82.2
	2	Concrete production.company	86.8
	3	Production Company for flags	89.2
	4	Production Company for bricks	98.7
Stonecutters	1	Al-Khayat stonecutter	93.2
	2	Al-Foriki stonecutter	95.6
	3	Al-Aghbar stonecutter	95.8
	4	Sbeah stonecutter	96.6
	5	Al-Sakhel stonecutter	97

4.2.Data analysis and discussion

The results obtained from the measurements are statistically representative of noise levels within the entire locations of the factories. The percentage of the measured L_{eq}- intervals is calculated and tabulated as shown in Table (4.3). The Percentage of noise level was calculated for each interval by dividing the number of factories on the total number of factories. A plot of the percentage of the L_{eq}-values in different factories is shown in Fig. (4.1).

Table (4.3): The percentage of the L_{eq}- intervals

L_{eq}- interval dB(A)	Number of factories	Percentage of L_{eq} (%)
$60 < L_{eq} < 65$	1	2.6
$65 < L_{eq} < 70$	1	2.6
$70 < L_{eq} < 75$	1	2.6
$75 < L_{eq} < 80$	2	5.3
$80 < L_{eq} < 85$	12	31.6
$85 < L_{eq} < 90$	10	26.3
$90 < L_{eq} < 95$	5	13.2
$95 < L_{eq} < 100$	6	15.8

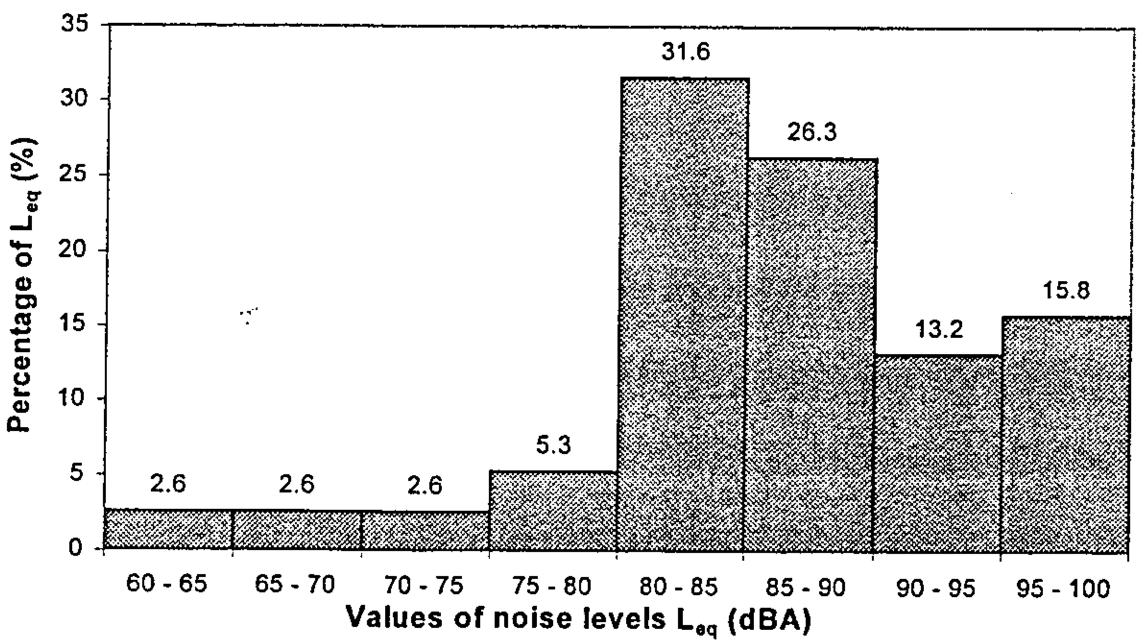

Fig. (4.1): Diagram of the percentage of L_{eq} against values of noise levels

About 2.6% of the total of factories considered in our sample which the L_{eq}-values range from 60 to 65 dB(A), generally considered as "acoustically undesirable" for the workers. In 37 factories (about 97.4% of the total sample), the values of L_{eq} exceed 65 dB(A), a noise level usually considered as "unacceptable" for the workers. It should be also observed that in about 92.2% of factories, the L_{eq}-values exceed 75 dB(A), which is an extremely high value for industrial areas. These measured L_{eq}-values are compared to the record issued by the Organization for Economic Cooperation and Development. (Amando Garcia, 1997).

The number of workers, average working hours and mean value are given in Table (4.4). Number of workers and average working hours are known from Table (4.1). Mean value (L_{eq}) is calculated from Table (4.2).

Table (4.4): Noise exposure in categories of factories

Category	Number of workers	Average working hours	Mean value L_{eq} (dBA)
Chemical	33	8	73.25
Plastic	427	10.5	82.24
Food	198	10.13	85.61
Paper and Wood	257	10.8	86.06
Metal	113	8.5	86.6
Concrete Production	84	9.75	89.2
Stonecutter	32	8.2	95.64

From Table (4.4), one observes that the chemical factories have the smallest L_{eq}-mean value, because the products have been gotten by using quiet machines. On the other hand, the stonecutters are the most noisy sources, because they emit extremely high noise levels. The plastic factories contain 37% of total workers who are exposed very long time to high noise. In food factories, the relative positions of the machines are too close to each other, so they emit continuously high noise levels.

A 23% of total workers are working in paper and wood factories, they expose to high noise levels daily. Moreover, the average working hours is about 10.8, which is the longest among all categories . In metal factories, the L_{eq} –mean value is very high. In concrete production factories, the size of machines is big, so they emit very high noise levels. The average noise exposure is the second highest among all categories.

The names of all factories, equivalent noise level (L_{eq}), actual exposure time (C_n), permitted exposure time (T_n) and the calculated noise dose (D) are given in Table (4.5). The actual exposure time is known from Table (4.2). But, the permitted exposure time can be calculated using the equation (1.5). Accordingly, the noise dose (D) can be calculated by using the equation (1.6). The standard error of D is 0.149.

Table (4.5): Calculations of noise dose (D)

No.	Name of factory	L_{eq}(dBA)	C_n(hr)	T_n(hr)	D
1	Al-Rajih factory(detergents)	69.7	8	133.4	0.06
2	Painting factory (Al-Arabia Factory)	76.8	8	49.9	0.16
3	Al-Aqad company(sewing machine)	63.9	10	298.2	0.03
4	Al-Tebey factory (spong)	72.2	8	94.4	0.08
5	Al-Aqad company(washers)	80.8	10	28.6	0.35
6	Al-Andalus factories(Nylon)	86.6	12	12.8	0.94
7	Plastic factory	87.8	8	10.9	0.73
8	Malheas factory(Shoes)	88.1	16	10.4	1.54*
9	Al-Aqad company(motors)	96.3	10	3.3	3.03*
10	Shalhoop roaster	81.2	9	27.1	0.33
11	Al-Deak factory(Fodder)	82.6	8	22.3	0.36
12	Qamhiya Tahina factory	84.1	8	18.1	0.44
13	Al-Zahraa factory(Juice)	84.4	8	17.4	0.46
14	Plaza factory	85	8	16	0.5
15	Al-Sanabel factory (Meat)	85.3	8	15.3	0.52
16	Al-Araz ice cream	90.4	24	7.6	3.16*
17	Tammam Tahina factory	91.9	8	6.1	1.3*
18	Al-Eqtesad Printery	79.7	8	33.4	0.24
19	Al-Horriya Printery	83.6	8	19.4	0.41
20	Al-Zaglol factory	83.7	20	19.2	1.04*
21	Al-Nasir factory	84.7	13	16.7	0.78
22	Al-Wafaa factory	85.9	8	14.1	0.57
23	Al-Najah Printery	86.4	8	13.2	0.6
24	Carton factory	92	13	6.1	2.13*
25	Hawash Company(Wood)	92.5	8	5.7	1.4*
26	Nickel and Golvan factory	83.9	8	18.6	0.43
27	Aluminum factory	84.5	10	17.1	0.58
28	Glass factory	88.3	8	10.1	0.79
29	Cans factory	89.7	9	8.3	1.08*
30	Al-Ekhaa flags factory	82.2	9	23.6	0.38
31	Concrete productions company	86.8	14	12.5	1.12*
32	Production Company for flags	89.2	8	8.9	0.9
33	Production Company for bricks	98.7	8	2.4	3.3*
34	Al-Khayat stonecutter	93.2	8	5.1	1.6*
35	Al-Foriki stonecutter	95.6	9	3.7	2.4*
36	Al-Aghbar stonecutter	95.8	8	3.6	2.2*
37	Sbeah stonecutter	96.6	8	3.2	2.5*
38	Al-Sakhel stonecutter	97	8	3.03	2.6*

If D > 1 in any factory, the measured L_{eq} – value is higher than the OSHA-Permissible noise exposure. So, the factory is considered noisy source. But, when D < 1, the measured L_{eq} – value is within the OSHA-scale. So, the factory is considered quiet source. According to the noise dose (D) and under the standard of OSHA-scale, the noise dose (D) must be less than unity. Therefore, the factories included in our sample are classified into two kinds, according to D, as given in Table (4.6).

Table (4.6): Classification of factories according to D

Noisy factories (D>1)	Quiet factories (D<1)
Malheas factory(Shoes)	Al-Rajih factory(detergents)
Al-Aqad company(motors)	Painting factory
Al-Araz ice cream	Al-Aqad company(sewing machine)
Tammam Tahina factory	Al-Tebey factory (spong)
Al-Zaglol factory	Al-Aqad company(washers)
Carton factory	Al-Andalus factories(Nylon)
Hawash Company(Wood)	Plastic factory
Cans factory	Shalhoop roaster
Concrete productions company	Al-Deak factory(Fodder)
Production Company for bricks	Qamhiya Tahina factory
Al-Khayat stonecutter	Al-Zahraa factory(Juice)
Al-Foriki stonecutter	Plaza factory
Al-Aghbar stonecutter	Al-Sanabel factory (Meat)
Sbeah stonecutter	Al-Eqtesad Printery
Al-Sakhel stonecutter	Al-Horriya Printery
	Al-Nasir factory
	Al-Wafaa factory
	Al-Najah Printery
	Nickel and Golvan factory
	Aluminum factory
	Glass factory
	Al-Ekhaa flags factory
	Production Company for flags

It can be seen that D exceeds unity in 15 factories. These factories emit excessive noise levels daily to be considered as pollutant sources to the workers. The table also shows those 23 factories, which D in them is less than unity to be considered as quite source.

The data of L_{eq}-values measured by using an integrating sound level meter are plotted as a function of time as shown in Figures (4.3-4.9)- listed at the end of this chapter- for each category of our sample. These figures show that the worker's exposure during a working time may vary from a noisy process to a relatively quiet one. In each category, there exist some factories, which emit high noise levels and others that emit low noise levels.

The data of L_{eq}-values were analyzed statistically using the SPSS program. Mean value, Median, Variance, Range, Minimum, Maximum, Standard Deviation and Standard Error were calculated and tabulated as shown in Table (4.7). All measures are given in unit of dB(A).

Table (4.7): Inferential statistics on L_{eq}-values

Category	Number	Mean	Median	Variance	Range	Minimum	Maximum	Standard Deviation	Standard Error
Chemical	2	73.25	73.25	25.2	7.1	69.7	76.8	5.02	3.55
Plastic	7	82.24	86.6	120.1	32.4	63.9	96.3	10.96	4.14
Food	8	85.61	84.7	13.6	10.7	81.2	91.9	3.69	1.3
Paper and Wood	8	86.06	85.3	18.7	12.8	79.7	92.5	4.32	1.53
Metal	4	86.6	86.4	8.07	5.8	83.9	89.7	2.84	1.42
Concrete Production	4	89.22	88.0	48.3	16.5	82.2	98.7	6.95	3.48
Stonecutter	5	95.64	95.8	2.19	3.8	93.2	97.0	1.48	0.66
Total	38	85.5	86.4	9.7	34.8	63.9	98.7	3.12	1.18

The standard error varies inversely with square root of number of factories and proportionality with the standard deviation. So, the standard errors are different in all categories of factories. For example, the standard error in chemical factories is high, since the number of factories is only 2. Also, the standard error in stonecutters is low, since the standard deviation is little.

The diagram of mean noise level for different categories of factories in Nablus City is shown in Fig.(4.2).

This figure shows that stonecutters have the highest noise level than the other categories. Also, the chemical factories have the lowest noise levels among the all categories.

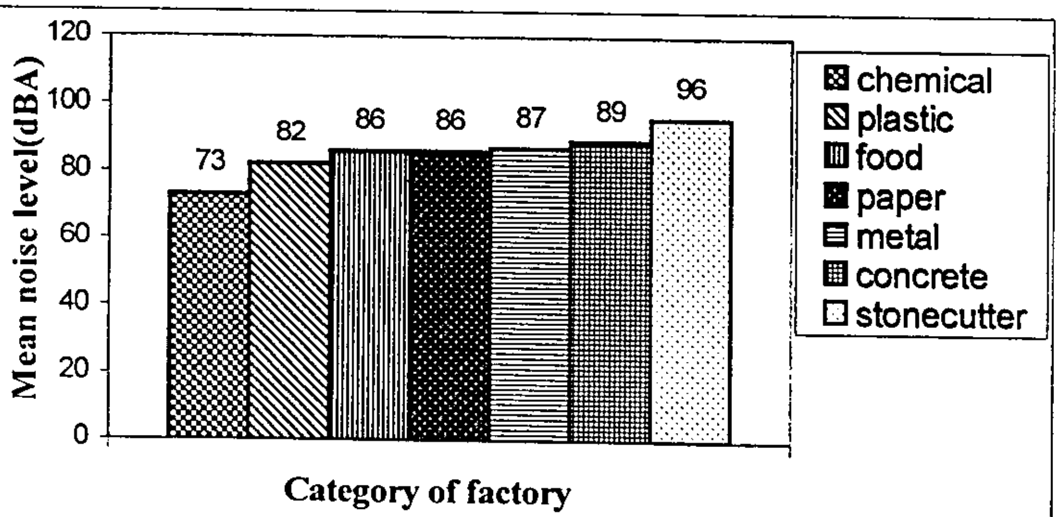

Fig (4.2) :Diagram of mean noise level agianst categories of factories

A significant effect for noise level in dB(A) on each dependent variable (mean value) was detected in this study by ANOVA test (TOKEY HSD). Table (4.8) gives the mean difference between factories, the standard error and the significant. The mean difference is significant when the level is less than 0.01. It is important to note that the mean difference between stonecutter and chemical factories is significant only. This means that the recipient can distinguish between the noise of these factories. The noise in other factories can not be distinguished since the mean difference between them is non-significant ($S > 0.01$).

Table (4.8): ANOVA Test :Tukey (HSD).

(I) Q1	(J) Q1	Mean Difference(I-J)	Standard Error	Significant
Chemical	Plastic	-8.9929	4.884	0.532
	Food	-12.3625	4.816	0.171
	Paper	-12.8125	4.816	0.143
	Metal	-13.3500	5.276	0.183
	Concrete	-15.9750	5.276	0.066
	Stone	-22.3900*	5.097	0.002*
Plastic	Chemical	8.9929	4.884	0.532
	Food	-3.3696	3.153	0.933
	Paper	-3.8196	3.153	0.884
	Metal	-4.3571	3.818	0.910
	Concrete	-6.9821	3.818	0.540
	Stone	-13.3971	3.567	0.011
Food	Chemical	12.3625	4.816	0.171
	Plastic	3.3696	3.153	0.933
	Paper	-0.4500	3.046	1.000
	Metal	-0.9875	3.730	1.000
	Concrete	-3.6125	3.730	0.957
	Stone	-10.0275	3.473	0.090
Paper	Chemical	12.8125	4.816	0.143
	Plastic	3.8196	3.153	0.884
	Food	0.4500	3.046	1.000
	Metal	-0.5375	3.730	1.000
	Concrete	-3.1625	3.730	0.978
	Stone	-9.5775	3.473	0.117
Metal	Chemical	13.3500	5.276	0.183
	Plastic	4.3571	3.818	0.910
	Food	0.9875	3.730	1.000
	Paper	0.5375	3.730	1.000
	Concrete	-2.6250	4.308	0.996
	Stone	-9.0400	4.086	0.318
Concrete	Chemical	15.9750	5.276	0.066
	Plastic	6.9821	3.818	0.540
	Food	3.6125	3.730	0.957
	Paper	3.1625	3.730	0.978
	Metal	2.6250	4.308	0.996
	Stone	-6.4150	4.086	0.702
Stonecutter	Chemical	22.3900*	5.097	0.002*
	Plastic	13.3971	3.567	0.011
	Food	10.0275	3.473	0.090
	Paper	9.5775	3.473	0.117
	Metal	9.0400	4.086	0.318
	Concrete	6.4150	4.086	0.702

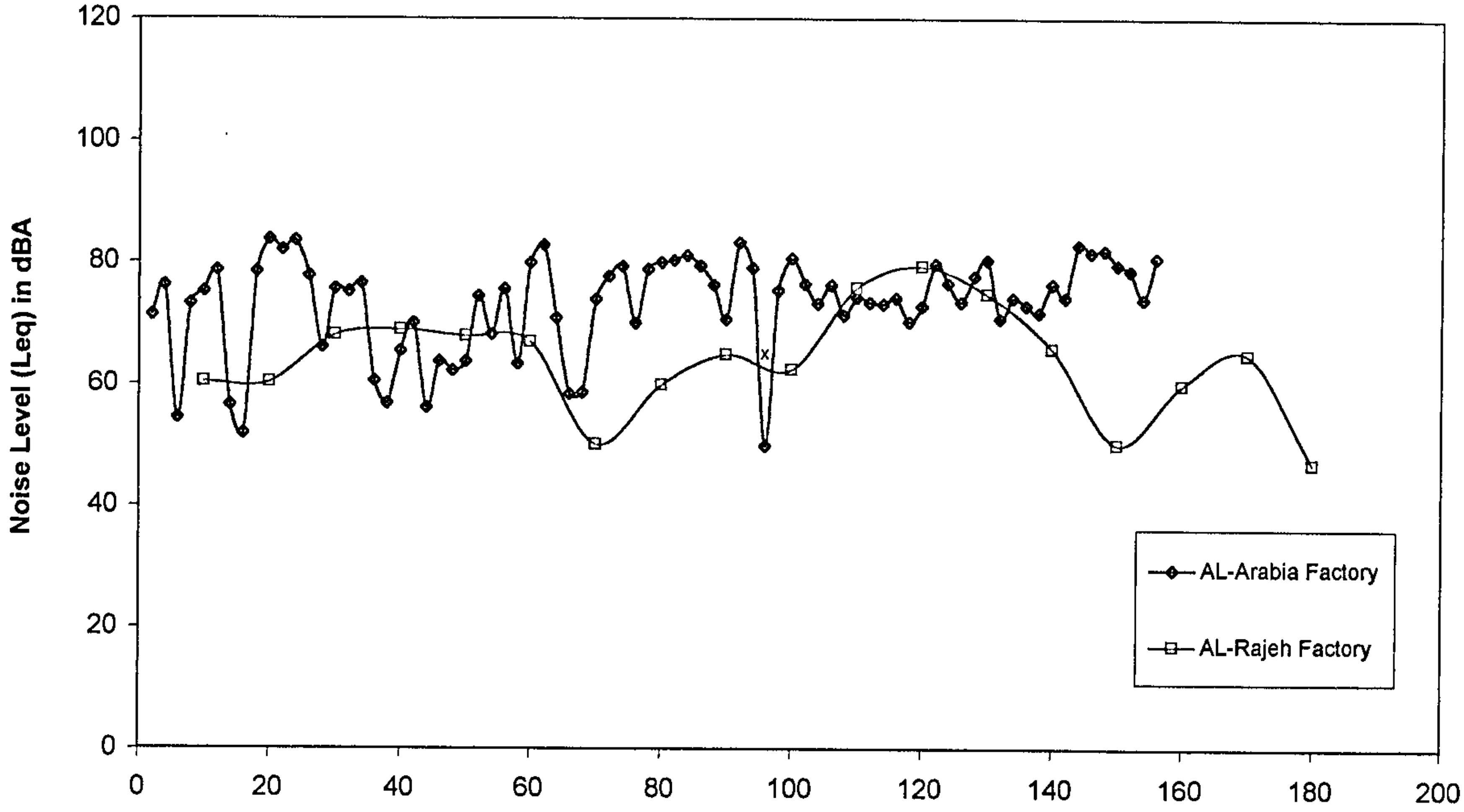

Fig.(4.3) : Noise pollution level versus time in chemical factories

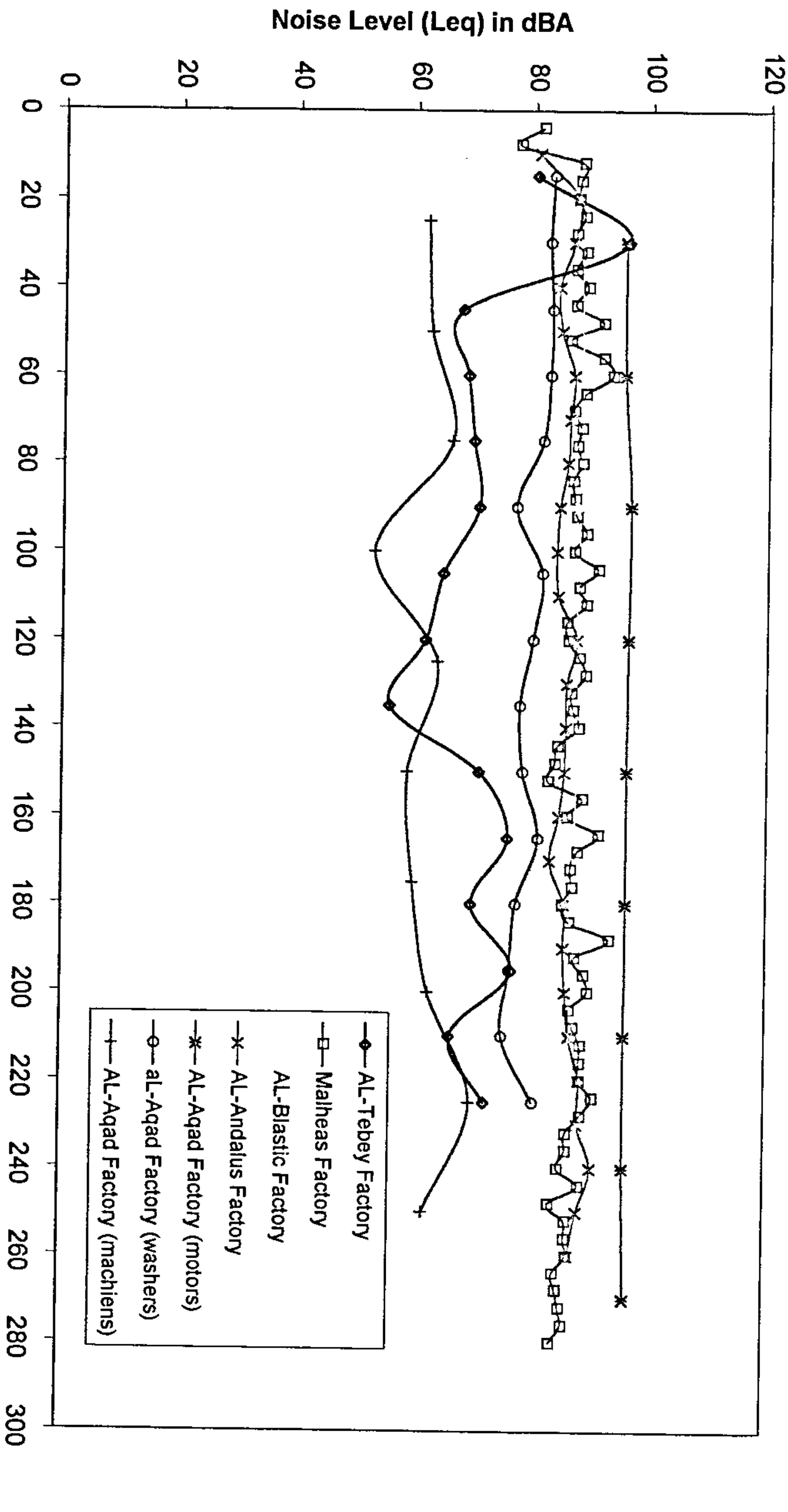

Fig.(4.4) :Noise pollution level versus time in plastic factories

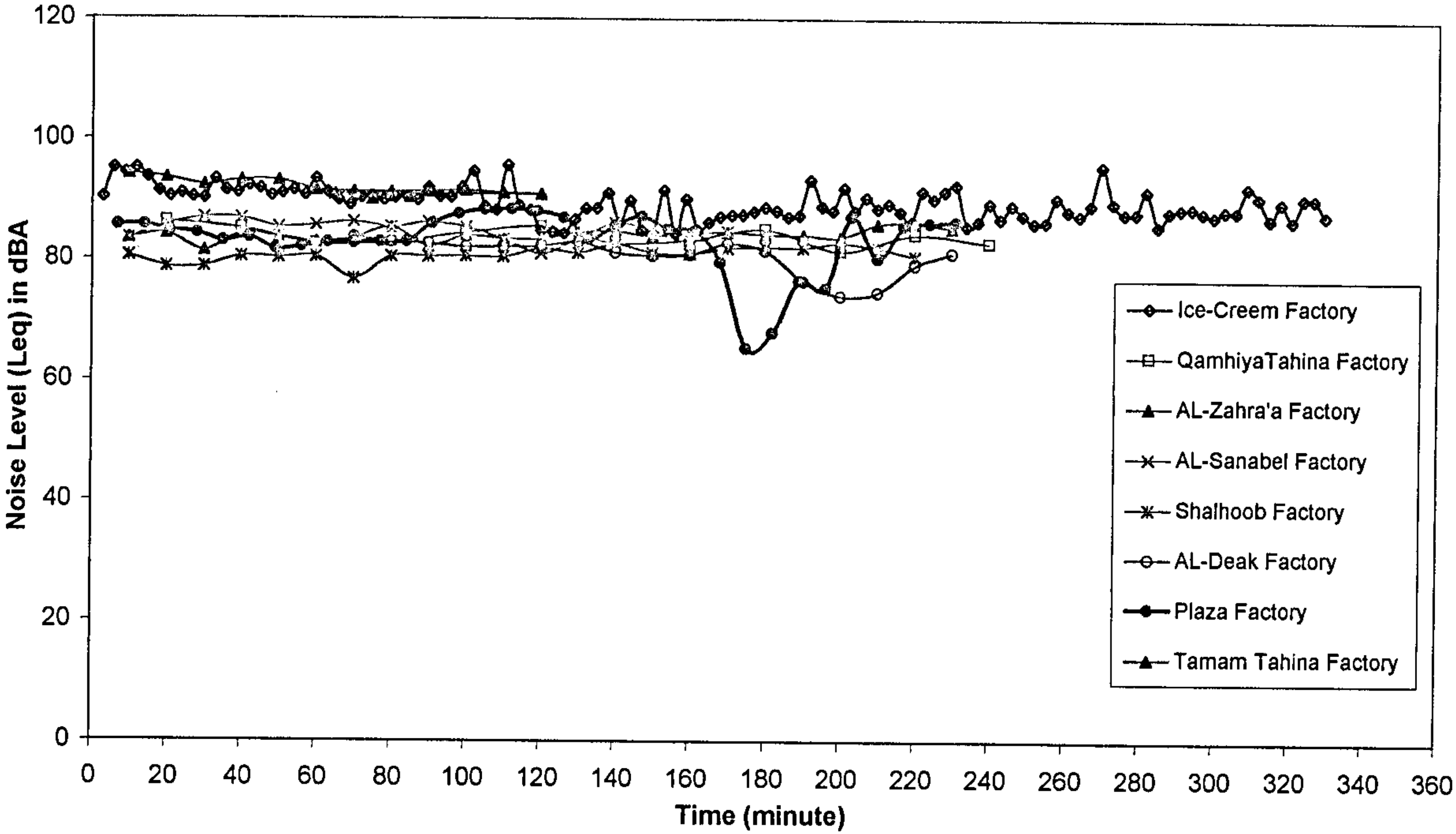

Fig. (4.5) Noise polltion level versus time in food factories

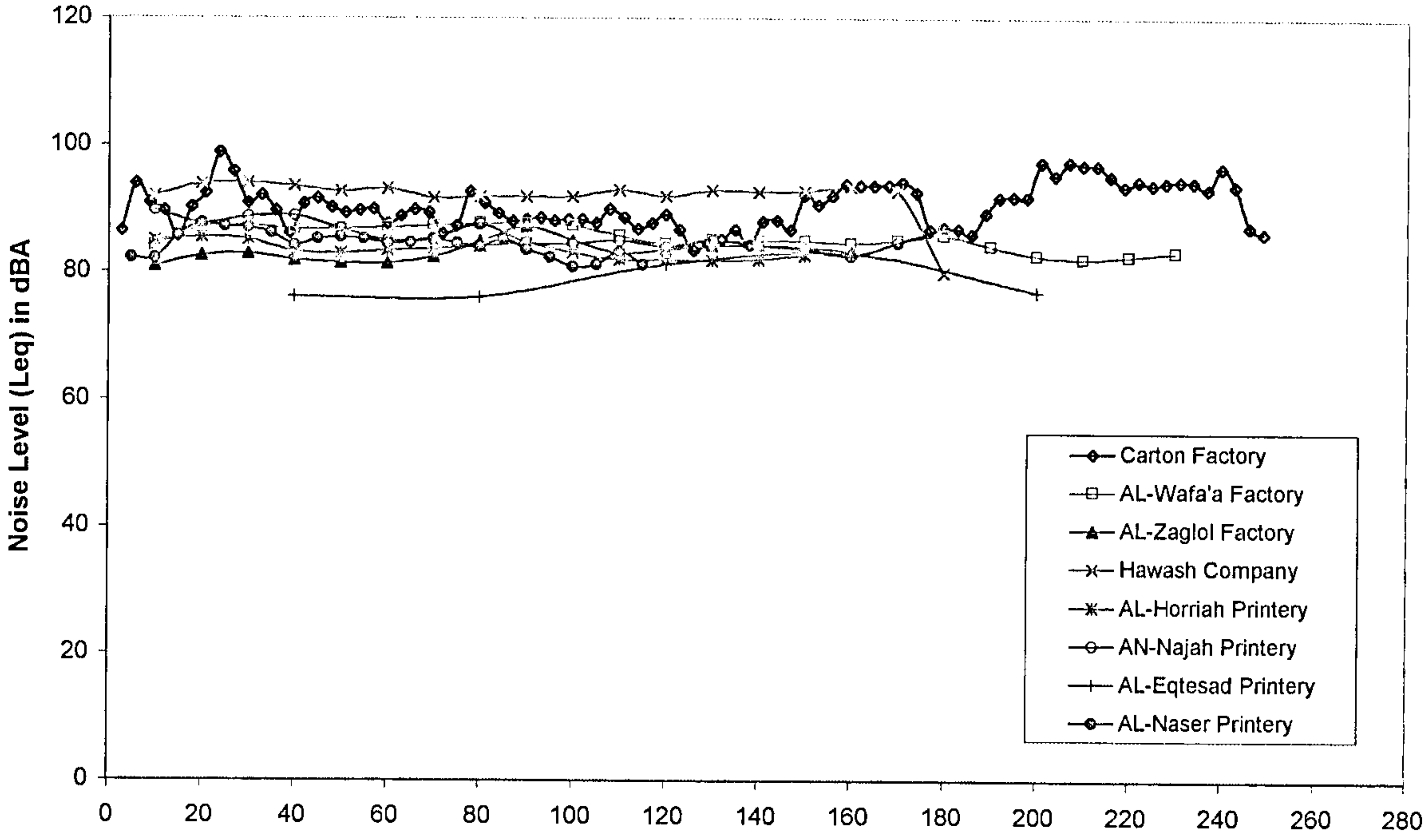

Fig. (4.6) : Noise pollution level versus time in Paper and Wood factories

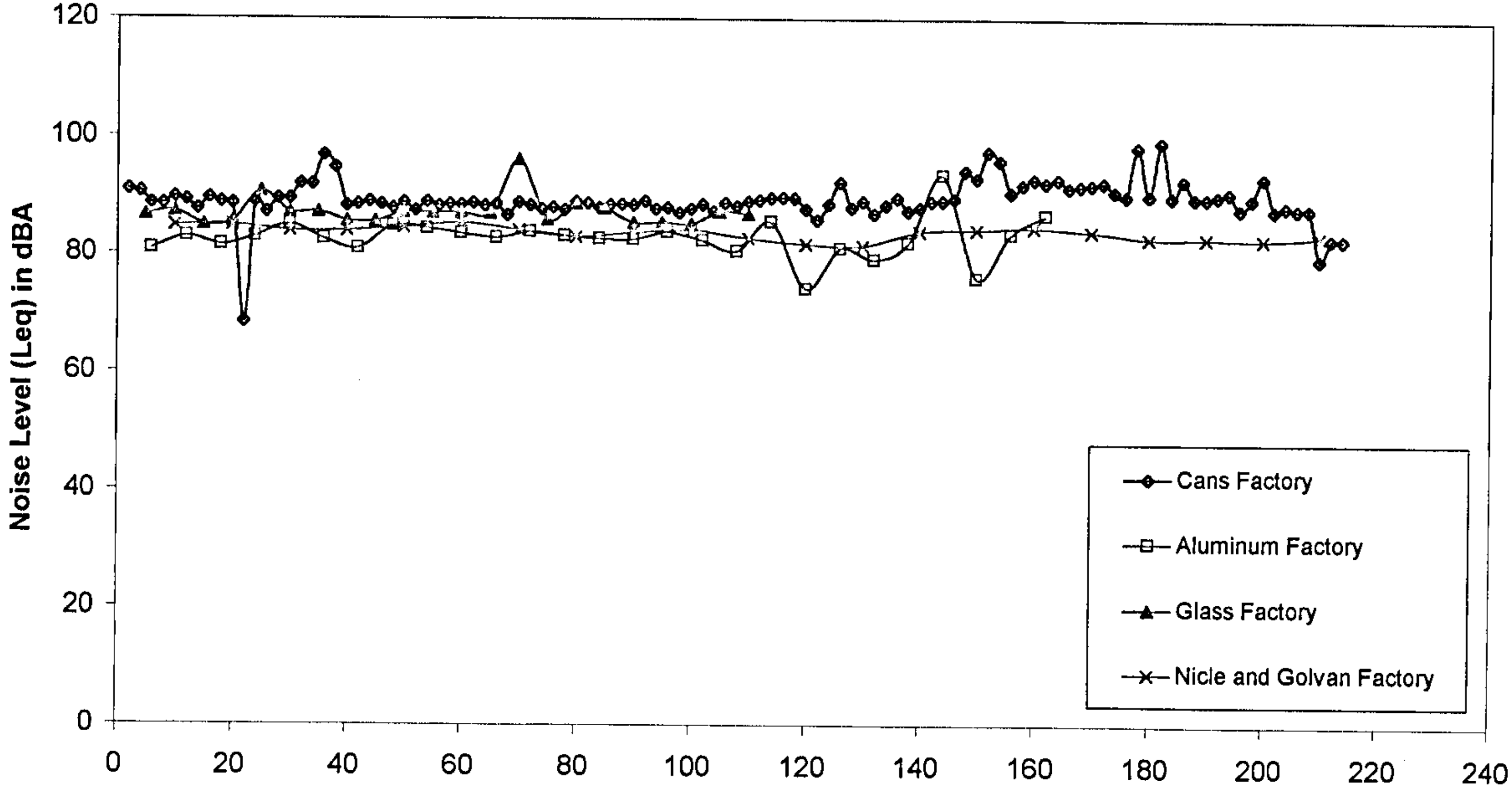

Fig. (4.7) :Noise pollution level versus time in metal factories

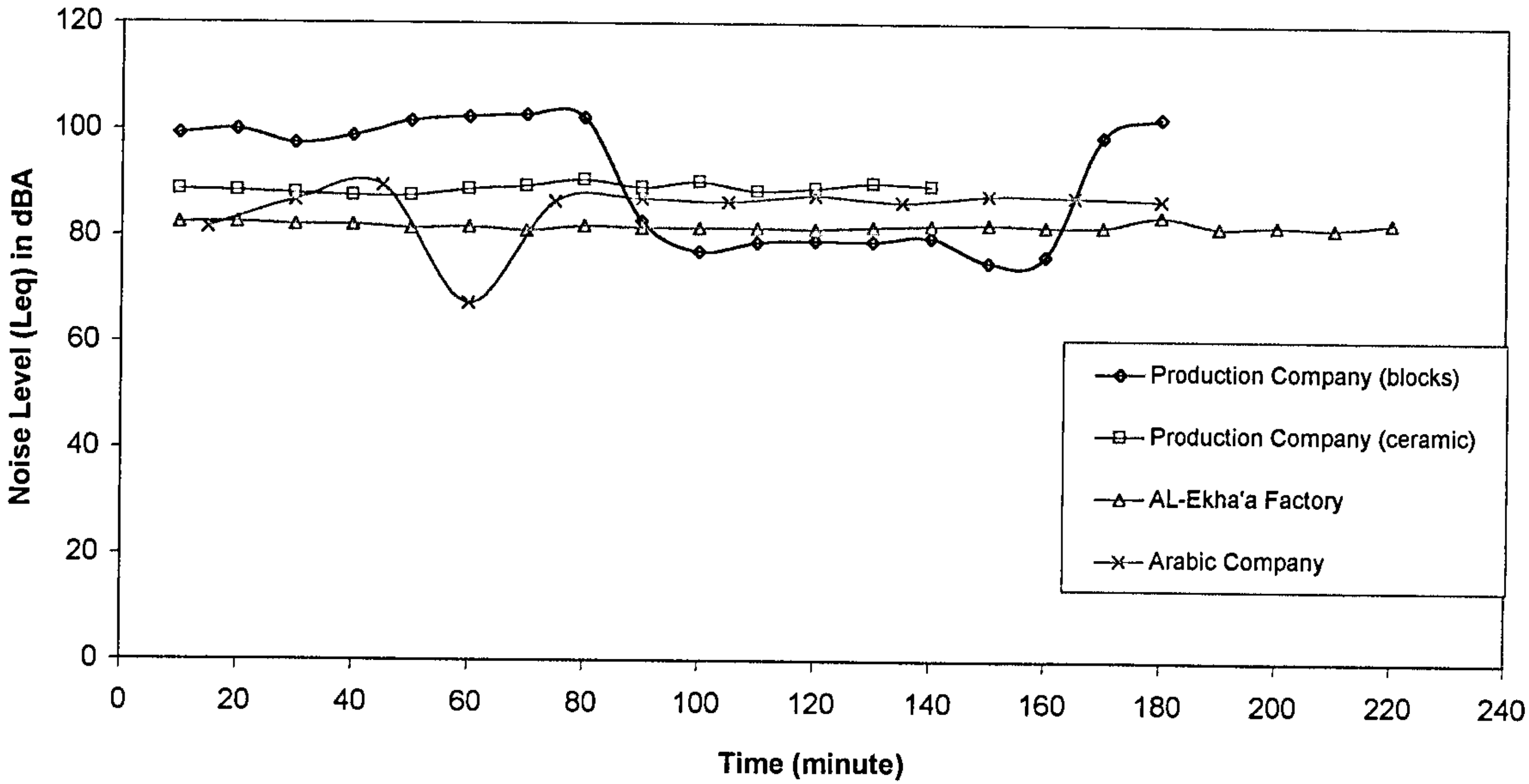

Fig.(4.8) : Noise pollution level versus time in concrete production factories

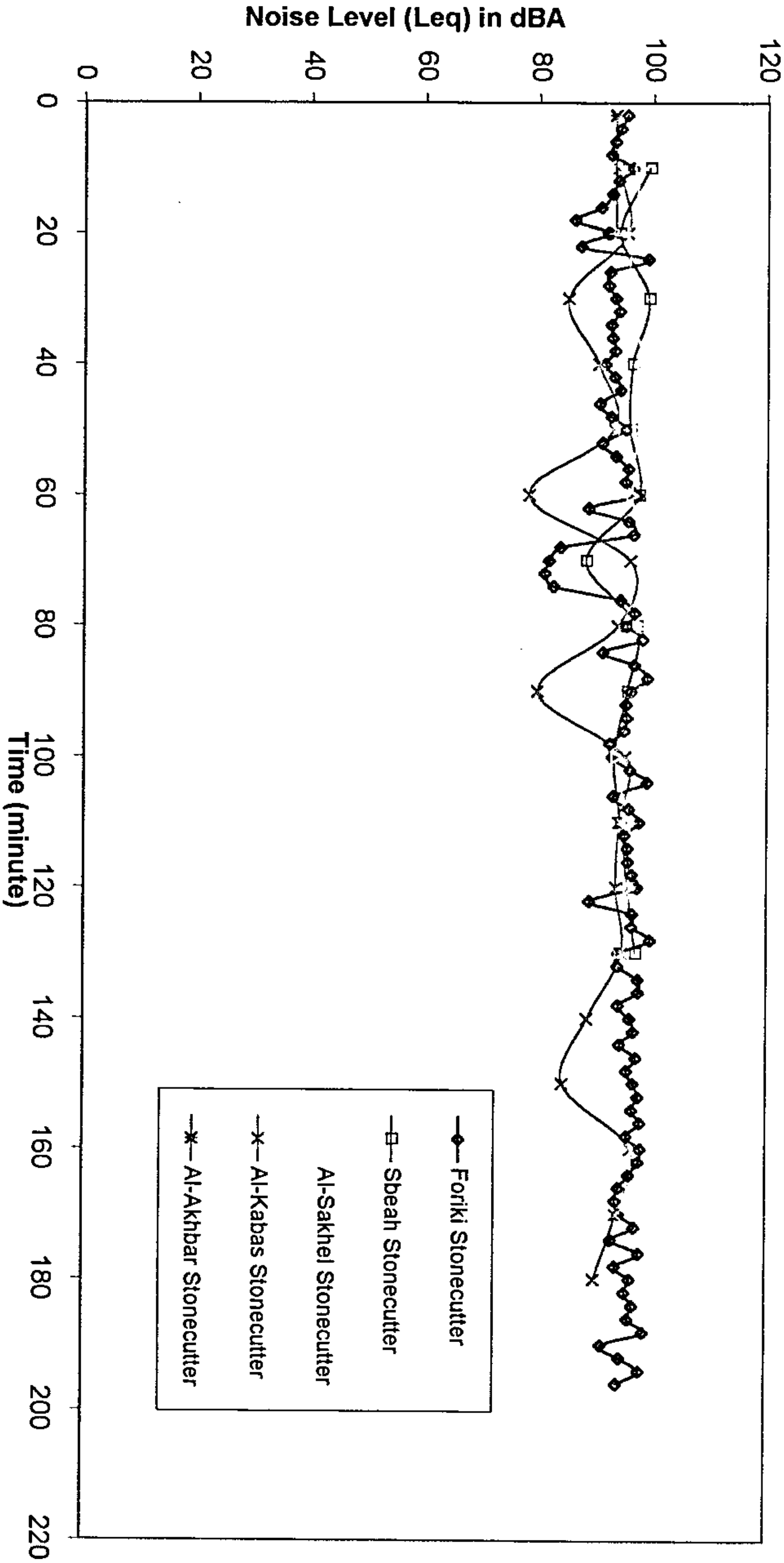

Fig. (4.9): Noise pollution level versus time in stonecutters

Chapter 5
Conclusions and Recommendations

The present measurements clearly showed that noise pollution levels measured in this work are very high. The workers in the sample factories are daily exposed to excessive noise levels. The percentage of people is highly annoyed by the industrial noise. The reported noise levels in 40% of the selected factories are much higher than the established limits for occupational noise exposure.

The wide variation of the noise levels in all factories indicates that there was no consistent policy followed across the board. This was presumably due to lack of any standard and lack of awareness amongst the factory owners.

A study of noise pollution, in which 38 factories were investigated, has been carried out in Nablus City. The conclusions based on data analysis performed from these factories are summarized as follows:

1- The mean equivalent sound levels measured in all factories included in this sample range from 73.25 dB (A) to 95.64 dB (A).

2- The average noise exposure level in stonecutters is the highest among all factories.

3- The average noise exposure level in chemical factories is the lowest among all factories.

4- The measured noise levels in 15 factories are higher than the established limits of standard noise.

5- The percentages of the workers who are exposed to noisy factories and quiet factories are approximately 49% and 51% respectively. But, due to the fact that the standard error of the L_{eq}-values is quite large, especially for those factories with small number of the selected factories such as chemical factories, see table (4.7), the accuracy of the percentage can never be less than 1%. Therefore, one can safely conclude that about 50% of the workers in Nablus factories are exposed to high noise levels, and of course 50% are not.

The calculated noise dose (D) in noisy factories exceeds unity, so we consider these factories as pollutant sources in Nablus City. These factories are considered undesirable areas for workers and noisy sources for residents. They emit extremely high noise levels daily, so the continuous exposure to such high noise can induce hearing loss among workers.

In industrial surroundings, the primary cause for complaint due to noise is nearly always linked to excessive sound levels, either within or external to industrial premises.

One of the cardinal rules in planning for noise control is to reduce the noise at its source by modification of the noise emitter, changing its operating conditions, or any other appropriate treatment. It will be necessary to use some form of solid object to destroy part of the sound energy by absorption, or to redirect part of the sound energy by wave reflection. In many practical applications an excessive sound level associated with a particular machine or group of machines is best handled by separating the offender from the worker by means of an acoustical partition. Two forms of total or partial containment of a sound field are recognized and will be termed barriers, and enclosures.

The acoustic barrier provides a possible means to reduce the sound pressure level due to the direct field of the source at a given position, for example, the acoustical walls are often used to separate excessively noisy machines from the majority of the workers in a plant situation.

Full Enclosures or Hoods are a special-purpose form of the acoustical enclosure designed for the express purpose of containing and absorbing the excessive acoustical energy of a machine.

Only the primary noise source should be enclosed, the enclosure walls

Should be constructed of a combination of materials that will provide absorption, isolation and damping. (Irwin J. *etal.* 1979).

The absorption characteristics of a material are dependent upon its thickness, density, and porosity, flow resistance and the fiber orientation. The materials may be prefabricated units, such as glass blankets, fiberboards; the material may also be a foam or open cell plastic. The absorption properties of materials vary with frequency. If the frequency of the noise is low, very little absorption occurs. But, if the incident noise is of high frequency, there is a good absorption material. (Irwin J. *etal.* 1979).

Noise reduction is imperative to protect workers from permanent hearing loss. This can be affected through insulation of the machines from workers and better maintenance of machines. The hearing conservation program, by undertaking periodic hearing tests, can also identify workers who have a high susceptibility to noise induced hearing loss.

Many recommendations can be put to relieve the noise pollution problem in the pollutant factories. Some of these are :

* For the owners of the factories:

1- Quieting the machines by

a- Allowing enough spaces between machines.

b- Use of acoustic barriers to shield, deflect, and absorb the noise.

c- Use a partial enclosure around the machine.

d- Reduction or elimination of noise leakage paths.

2- Limiting the exposure time.

3- Not to build factories in residential areas.

* For the workers in the factories:

1- Using ear protectors for workers.

2- No exposure to high noise very long time.

3- Undertaking periodic hearing tests.

4- "Prevention is better than cure".

* For the Palestinian authorities:

1- Setting up industrial noise surveys and ordinances.

2- Planning for an early step in any noise control program for industrial or residential areas.

3- Following safety and health regulations by applying the ISO.

4- Following maintenance of the machines.

At the end of this study, we could find that there are number of factors that determine the noise levels in an area of factory.

These are: the relative positions of the machines, their sizes, how noisy they are individually, and the size of the area.

That factors should be studied in the future to explore whether the factory is more noisy or not.

Finally, the continued actions of autonomous and local administrations on this subject are also essential. It seems evident that, in the future, much more effort will need to be exerted to reduce the present levels of industrial noise pollution in factories of Palestine.

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Appendix A
Terminology

Permanent damage: Noise induced hearing loss (NIHL), occurs when exposure to excessive noise continues over a long period of time.

Noise regulations: An authoritative rule dealing with details of procedure for noise control (a regulation principle or law).

Noise standard: A documented method, procedure, or specification related to some aspect of noise (measurements, its effect on people, permissible levels).

Noise indices: The quantitative aspect of a rating scheme, which gives a measure of community response to noise.

Sound Pressure Level (SPL): A measurable sound level that depends upon environment. Expressed in (dB) at a specified distance and position.

Sound Power Level (SWL): The amount of sound output from a machine, etc. Can not be measured directly. Expressed in (dB).

Sound-absorption coefficients: The ratio of the acoustical energy absorbed by the surface to the acoustical energy incident upon the surface when the incident sound field is perfectly diffused.

Masking: Extra sound introduced into an area to reduce the variability of fluctuating noise levels or the intelligibility of speech.

Sound Level Meter (Noise Meter): An instrument for measuring sound pressure levels. Can be fitted with electrical weighing networks for direct read in dB(A),dB (B),dB(C) and dB(D).

Background noise: The existing noise associated with a given environment. Can be sounds from many sources, near and far.

Pure tone: A single frequency signal.

Free field: A sound field which is free from all reflective surfaces.

Threshold of audibility: The minimum sound levels of each frequency that a person can just hear (also called threshold of hearing).

Hazardous noise: Any sound capable of causing permanent damage to the sense of hearing of human beings.

Hearing level: The number of decibels by which some quantity related to sound or hearing is above (+) or below (-), the standardized audiometric zero at a specified frequency.

Acoustics: The science and technology of sound, including its production, transmission and effects.

Hearing loss: A hearing level in dB that relates specifically to a raised (+) permanent auditory threshold for an individual.

Damage–risk criteria: Specify limitation on personal noise exposures which, if not exceeded, ensure that the risk of hearing damage to a group is acceptably small.

Impairment: A physical or mental handicap that qualifies under the Americans with Disabilities Act for protecting the workers from discrimination in employment.

Continuous noise: If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous.

Equivalent continuous sound level: The level of a steady sound which, in a stated time period and at a stated location, has the same A- weighted sound energy as the time varying sound.

Weighting: A prescribed frequency response provided in a sound level meter.

Reference: (Harris, 1979)

الملخص بالعربية

إن التلوث الضوضائي قضية لها أهمية متزايدة، خاصة في البلدان الصناعية، حيث أن الضوضاء الصناعي يعد مشكلة بيئية حقيقية تسبب لنا الإزعاج وتعرقل نشاطاتنا اليومية.

في الضفة الغربية، على الرغم من عدم وجود قوانين منظمة لتحديد مستوى الضجيج الصناعي وعدم الوعي بالتأثيرات السلبية لمستويات الضجيج العليا، فان أصحاب المصانع لا يعيرون أي انتباه لتوفير قياسات مناسبة للضجيج لحماية العمال.

لذلك السبب فقد ركزت هذه الدراسة على قياس مستويات الضجيج المكافئة في 38 مصنعا في مدينة نابلس ثم مقارنتها بالمقاييس العالمية للضجيج.

أوجدت هذه الدراسة أن معدل الضجيج الناتج هو 85.5 dB(A) وان قيم الضجيج في 40 % من المصانع المختارة هي أعلى من المقاييس العالمية المقررة، لذلك اعتبرت هذه المصانع مزعجة للعمال. إن تعرض العمال المستمر لمستويات الضجيج هذه تسبب انهيار السمع، الكلام الغير واضح والإزعاج.

مستوى الضجيج العالي المعتمد على قيمة المستوى ونوعيته ومدة التعرض لا يعوق الاتصال بين العمال فحسب، وإنما يسبب تأثيرات فيزيائية، وظائفية ونفسية على العمال.

اقترحت هذه الدراسة بعض التوصيات والنصائح لعمال المصانع، وأصحاب المصانع وللمسؤولين الفلسطينيين، وذلك لتقليل مشكلة التلوث الضوضائي في المصانع في مدينة نابلس.