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A Study of Noise Pollution in Zarqa and Irbid, Jordan

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ABSTRACT

Zarqa and Irbid, Jordan are two of the most populated cities. They are environmentally noise polluted due to the rapid and widespread introduction of mechanical methods for production of goods and equipment and for their transportation. L10, L50, L90 and LAeq noise levels were measured during the day time and night time to assess and evaluate the noise levels from mosques, schools, celebration halls, streets, construction and building works, industrial areas and commercial areas. This -coupled with a social survey- were conducted in the two cities to understand the physiological and psychological effect of noise on people, and to study the extent of annoyance on people. There is a significant correlation between the measured statistical noise levels L10, L50 and L90 and equivalent continuous noise level LA_{eq}, and this correlation differs from Zarqa to Irbid due to the differences in noise levels that can be explained by the differences in the nature of traffic in these cities. The results of the investigation showed that the measured noise levels from all the selected sources were high during the day time and night time, and the noise problem is not only limited to day time, but continues in night time in these cities, and a sound at night may be more annoying than that heard during the day. And these noise levels were higher than those set by Jordanian limits during day time and night time. Also, the results indicated that Zarqa city is somehow noisier than Irbid city during both the day time and night time hours. The results of the social survey revealed that the exposure to high noise levels will affect the people in terms of annoyance depending mainly on the individuals, sleep disturbances, effect on the ability to work, loss of concentration, and will affect the health and cause hearing problems. Also, the results indicated that the gender type, age, educational level and employment state are directly related to their annoyance level and awareness about the noise problems.

KEYWORDS: Noise pollution, Sound levels, Annoyance, Social survey.

INTRODUCTION

The population of Jordan increases year by year, with a growth rate of about 2.49% reaching 5,906,760 inhabitants (CIA World Fact Book, 2006). This, coupled with the rapid and widespread introduction of mechanical methods for production of goods and equipment and for transportation, created new conditions of living. These conditions added a new factor to air, water and soil pollution, called noise which increased in a greater rate than the population. The city of Zarqa with a population of about 850,000 inhabitants and the city of Irbid with a population of about 1 million inhabitants are two of the most populated cities in Jordan, they are environmentally noise polluted. One of the earliest studies concerned with noise pollution was carried out by White (1975), who showed that noise levels increase with increasing urbanization, just as other forms of pollution are aggravated by the increase in population density.

At present, there is great concern about the occurrence of unwanted sounds, commonly called noise, and their

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possible effects upon man (Burns, 1973). Noise may be defined as any sound that annoys or disturbs humans or that causes or tends to cause an adverse psychological and physiological effect on humans (Davis and Masten, 2004; Comb and Taylor, 1978). Noise can also be considered an environmental pollutant, a waste product generated in conjunction to various anthropogenic activities that may interfere with social ends of an individual or group (Davis and Masten, 2004). Noise in the environment has a unique situation that complicates its adequate comparison to other environmental contaminants. So, the essential problem is to find the relation between the physical aspect of the noise and the effect it produces.

Even from earliest days, our advancing technology has been accompanied by an increase in environmental noise. Two types of noise emissions are of concern: (1) impulsive noise – that is, noise of short duration and high density such as explosions, sonic booms and artillery fires, and (2) continuous noise – that is, noise of longer duration and lower intensity such as that from construction works or traffic (Canter, 1996). The daily lives of people, particularly in urban communities, have been more and more invaded by noise from different sources. These sources include construction works and industrial machinery, in addition to office and household equipment. Noise is associated with every type of human activities, machinery, office equipment, traffic, aircraft, television and radio, loading and unloading operations, vehicle repair activities and vibrations (White, 1975; Comb and Taylor, 1978). Additionally, it has been reported that traffic is one of the major sources of noise (Skanberg and Ohsrom, 2002). The noise due to the traffic along a road is continuously fluctuating and is not easy to forecast or quantify (Stoilova and Stoilov, 1998).

It should be noted that most of the available literature about the subject of noise pollution deals primarily with traffic noise. An investigation reported by Piccolo et al. (2004) indicated that main roads of Messina, Italy are overloaded by traffic flow during daytime and that more than 25% of the residents are highly disturbed by road traffic noise. In a recent study dealing with urban noise pollution conducted by Calixto et al. (2003), 73% pointed to traffic as the main noise source among all the respondents who felt annoyed by the noise generated in streets.

This is particularly important for the Jordanian cities. Jamrah et al. (2006) reported that the number of vehicles in Jordan has increased from about 20,000 to approximately 310,000 between the years 1970 and 1997, which represents an average annual increase of about 53%. Between the years 1997 and 2005, the national vehicle registration jumped from 310,000 to 575,000, which represents an average annual increase of about 11%. Traffic noise pollution in the city of Amman, the capital of Jordan, was evaluated by Jamrah et al. (2006). Their study showed that the minimum and the maximum noise levels are 46 dB (A) and 81 dB (A) during the day and 58 dB (A) and 71 dB (A) during the night. Additionally, the measured noise level exceeded the 62 dB (A) acceptable limit at most of the locations. The study also investigated that the Calculation of Road Traffic Noise method (CRTN) can be applied to predict road traffic noise for the conditions of road and traffic flow in Amman. Also, this method was more reasonable in predicting nighttime noise level than daytime noise level, indicating higher levels of noise in the absence of traffic noise.

It has been concluded in a study conducted by Georgiadou et al. (2004) in Thessaloniki, Greece, that there is a significant correlation between traffic noise and mean traffic volume. In addition, the mean daily values; L_{eq} (08:00-20:00), are close to the national limit of 67 dB (A). The measurements showed that Thessaloniki experiences a problem with noise level, which, given the annual average increase in traffic volume of 6% during the past decade, might get worse. Similarly, measurements of traffic noise levels in Muscat city carried out by Al-Harthy and Al-Jabri (2006) indicated higher noise levels than those set by the Omani noise standard of 65dB(A) for residential areas.

The results of the study carried out in Dar es Salaam International Air Port (DIA) by Mato and Mufuruki (1999) have revealed that the current operation of (DIA)

results in high noise levels from landing and take–off of aircrafts. Measured noise levels in the airport as a whole are expected to have negative health effects on the workers. Additionally, the study revealed that the use of appropriate ear protectors by the workers may offset the noise risk to a great extent. Similar results obtained by Franssen et al. (2002) indicated that exposure to aircraft noise of Amsterdam Airport affected the health status of the population living around the airport in terms of annoyance, sleep disturbances, cardiovascular diseases and reduced performance.

Noise pollution leaves no residue in the body, therefore, it is difficult to measure its cumulative effects or distinguish noise impacts from other similar stressors (Schmidt, 2005). The World Health Organization (WHO) recommended in 1997 a noise level of less than 35dB (A) $L_{eq.}$ A long term exposure to noise levels of about 90dB (A) may lead to permanent hearing loss; while prolonged exposure to noise of 100dB (A) may cause irreparable damage to the auditory organs. A noise level of about 120dB (A) is considered painful and may cause instantaneous loss of hearing; while more than 140dB (A) may produce insanity (Mato and Mufuruki, 1999).

Health impacts associated with noise pollution were investigated by Burns (1973) who pointed out that the effect of noise can conveniently be accommodated within two categories: direct effects on the individual, and indirect effects on the individual. The direct effects include loudness sensation, interference within perception of speech or difficultly in hearing sound signals. The indirect effects include the disturbance of sleep or rest, annoyance, disturbance of activities involved in work or leisure and possible effects on health.

Many problems arise from noise, ranging from annoyance to insanity and death. Noise has been reported to affect the auditory system, sleep quality, heart rate and stress related ischaemic heart disease, including various impacts on the mental and cardiovascular systems. Additionally, noise disrupts and interferes with the speech communication and prevents creative activities. Furthermore, Noise intrusion can decrease children learning skills, productivity and performance (Mato and Mufuruki, 1999; Georgidou et al., 2004; Piccolo et al., 2004; Levins and Gillen, 1998). Davis and Masten (2004) showed that noise of sufficient intensity and duration can induce temporary or permanent hearing loss, ranging from slight impairment to nearly total deafness. In general, a pattern of exposure to any source of sound that produces high enough levels can result in temporary hearing loss. Exposure persisting over time can lead to permanent impairment.

Health impacts related to noise are hard to quantify, but because they are associated with a place, the quantity of damage is often viewed as resulting in lower property values. Levinson and Gillen (1998) investigated the decline in residential property value due to noise and its associated vibration. They defined the Noise Depreciation Index (NDI) as the percentage reduction of house price per dB (A) above some base, and employed this index to determine the amount of noise damage produced by a facility. It should be noted that reasonable estimates should rely on accurate knowledge of noise produced on the facility and the location of residences near the facility.

Extensive literature is available on the subject of noise pollution. However, the necessary information is to some extent elusive. This is because noise is a subjective experience. What is considered noise by one listener may be considered desirable by another. Burns (1973) and White (1975) showed that sound that might be enjoyable to some people may be intolerable to others, depending upon a person's interests, activity and mood. A sound at night may be more annoying than during the day. Additionally, a sound that fluctuates may be more annoying than one that does not (Davis and Masten, 2004). Noise has a short decay time and thus does not remain in the environment for long, as air and water pollution do, finally it becomes difficult to associate cause with effect (Davis and Masten, 2004; Comb and Taylor, 1978).

Environmental Impact Assessment (EIA) studies nowadays include components of projects dealing with health. Franssen et al.(2002) indicated that the scope of a health impact assessment depends on the situation, available knowledge and data, concern in the population

about the impact and the number of people concerned. The coverage of human health aspects in EIA studies still tends to be limited, and there is a lack of systematic approach or methodology. Canter (1996) showed that there are six generic steps associated with noise environmental impacts: (1) Identification of level of noise emissions and impact concerns of the development project. (2) Description of the environmental setting in terms of existing noise levels and noise sources. (3) Procurement of relevant laws, regulations or criteria related to noise level. (4) Conduction of impact prediction activities, including the use of simple noise attenuation models, simple noise – source – specific models, comprehensive mathematical models and / or qualitative – prediction techniques based on the examination of case studies and the exercise of professional judgment. (5) Use of pertinent information from step 3, along with professional judgment and public input. (6) Identification, development and incorporation of appropriate mitigation measures for the adverse impacts.

Al-Harthy (2006) and Zannin (2002) showed that monitoring, testing, evaluating and promoting the awareness of the population about the risks of daily exposure to high noise levels are important tools in the management of noise problems. Piccolo et al. (2004) pointed out that the desirable mitigation measures in the case of traffic noise pollution include finding a new location for the landing places far from residential areas to decongest the urban center from the heavy traffic.

The main objectives of this study are: (1) to asses and evaluate noise levels from different sources in the selected sites, (2) to understand the physiological and psychological effects of noise on people and understand the relation between noise and public reaction, (3) to study the extent of annoyance by different noise sources and to what extent people could become accustomed to noise and tolerate it and (4) to carry out a comparative assessment of noise in the selected Jordanian cities, Zarqa and Irbid.

METHODOLOGY

This study was conducted between June and December 2007. A parallel investigation of this study was carried out in the selected cities in Jordan (Zarqa and Irbid). Different areas of the cities were surveyed in different times during a day. Participants in the social survey were selected randomly to represent different categories of age groups, education, gender and employment state. Special attention was given to some noise sources, including big cars (trucks), TV, stereo and music, parties, birds, azan, normal cars, planes, factories, schools, garbage cars, water supply engines and construction and building works. This enabled the evaluation of environmental noise pollution in the selected cities in Jordan due to different noise sources. Additionally, it enabled the assessment and rating of noise exposure in the different cities.

Social survey questionnaires were designed to measure the subjective reactions to noise, to obtain some indication of the annoyance caused by sound and to understand the psychological evaluation of the individuals to their environment. Additionally, the social survey attempted to identify the perception of people towards noise as being an environmental pollution and health hazard, and to investigate the consequences of noise pollution on the way of living.

Individuals participating in the survey were requested to respond by yes, no or somehow to the following questions: (1) Are these sounds observable in your city; big cars (trucks), TV, stereo and music, parties, birds, azan, normal cars, planes, factories, schools, garbage cars, water supply engines and construction and building works? (2) Do you prefer to hear these sounds? (3) Are these sounds audible at your home? (4) Classify these sounds as follows: not annoying at all, a little annoying, moderately annoying and very much annoying, (5) Do you think that the noise resulting from these sounds causes a big problem in your life? (6) Does the noise produced by sound lead to wake you up, interfere with listening to TV or radio, interfere with normal activities such as conversation, disturb you and let you lose concentration, affect your ability and performance and annoy you in any other way? (7) How many hours do you need to cope with the noise: < 1 hours, 1-3 hours, 4-6

hours, 7-9 hours, 10-12 hours and > 12 hours? (8) Do you think that noise has a negative effect on your health? (9) Did you suffer any hearing – relating problems caused by these sounds? (10) Do you consider that noise an environmental pollutant and environmental nuisance? (11) To what extent do you consider noise pollution an important issue in your city? and (12) Do you consider that moving your place of residence is an appropriate solution to the problem?

Table (1): Basic principles of attributes for respondents of the survey in Zarqa and Irbid.

Zarqa city				**Irbid city**			
Gender	**Age (years)**	**Education**	**Employment state**	**Gender**	**Age (years)**	**Education**	**Employment state**
Male: 132 (52.80%)	15-27: 148 (59.20%)	Literate: 228 (91.20%)	Student: 114 (45.60%)	Male: 134 (38.29%)	14-29: 268 (76.57%)	Literate: 323 (92.29%)	Student: 223 (63.71%)
Female: 118 (47.20%)	28-40: 60 (24.00%)	Illiterate:22 (8.80%)	Employee: 111 (44.40%)	Female: 216 (61.71%)	30-45:56 (16%)	Illiterate: 27 (7.71%)	Employee: 73 (20.85%)
	41-53: 32 (12.80%)		Unemployed: 3 (1.20%)		46-61:24 (6.86%)		Unemployed:8 (2.29%)
	>53: 10 (4.00%)		Housewife: 12 (4.80%)		>61: 2 (0.57%)		Housewife:15 (4.29%)
			Other: 10 (4.00%)				Other: 31 (8.86%)

Noise levels are measured by a Reten Electronic RS – 232 Data logging sound level meter with an (A) weighted sound pressure level. The measuring range is 30 dB(A) – 130 dB(A), and the noise is given as dB(A). This measuring range can be changed allowing the sound level meter to be used for different ranges of noise levels, where both high and low sound levels occurs. Noise was measured 1m away from the source and 1.5m above ground, ensuring that the microphone was pointed towards the source.

A sound meter is an instrument which responds to sound in approximately the same way as the human ear and which gives reproducible measurements of sound level (Mato and Mufurki, 1999).

Measurements were done at 35 different sites selected in Zarqa and 35 different sites selected in Irbid city. Measurements included five main streets of Zarqa and Irbid city with quite high traffic volume. Each of the 35 sites in Zarqa and Irbid city was monitored during the day time hours (7:00 am - 4:00 pm) within five days for each city and during night time hours (5:00 pm – 10:00 pm) also within five days for each city. All measurements took place in conditions with no wind and no rain. Noise levels were assessed for the most sources mentioned in the questionnaire; traffic noise, industrial area noise, commercial area noise, mosques noise, schools noise, celebration halls noise and construction and building works noise. The noise exposure levels from each of these sources were assessed for LA_{eq} for 1hr (within 2 – second intervals during the 1hr monitoring period) during the day and for 1hr during the night in order to assess the impact of noise on the residential areas and carry out a comparison between the day time and the night time, and to compare the average LA_{eq} value of day and night times with the national ambient noise quality standard. Percentile levels L10 day and night, L50 day and night and L90 day and night were also measured.

The equivalent continuous sound level LA_{eq} represents the constant noise level containing the same quantity of sound energy over a time period as the actual

varying noise level (Georginadou et al., 2003; Davis and Masten, 2004), which is very widely used, since it allows a simple quantification of noises which may often vary in a highly non - stationary manner (Stoilva and Stoilov, 1998), normally L10 (noise level exceeding 10% of the time) represents the average of the noise peaks, L50 (noise level exceeding 50% of the time) is near to the mean level for dense traffic and L90 (noise level exceeding 90% of the time) may be considered as background noise (Pandya, 2003).

RESULTS AND DISCUSSION

Social Survey on Noise in Zarqa and Irbid City

The study tried to cover most sectors of citizens in Zarqa and Irbid. The study covered in total 250 respondents in Zarqa and 350 respondents in Irbid.

Table (1) shows that the considerable numbers of respondents to the Zarqa survey were literate males between 15-27 years old, while the considerable numbers of respondents to the Irbid survey were literate females between 14-29 years old. Old respondents and unemployed respondents in both surveys were few. Most of old people are living in suburbs far away from crowded, noisy cities, old people after procuring their retirement prefer to leave cities and live in quiet and convenient places (Al-Harthy et al., 2006).

Reactions to Q1 and Q2, Figure (1) and Figure (2) show the observed and preference rate of sounds in Zarqa and Irbid city, respectively. These results are similar to those presented by Al-Harthy and Al-Jabri (2006). The sound of azan was the highest rate observed over 91% in Zarqa and over 92% in Irbid, while respondents to the Muscat survey carried out by Al-Harthy (2006) pointed out that the sound of normal cars was the highest rate observed over 90%, and then the preference was 47.6%. 1.6% of the respondents to the Zarqa survey who heard the azan sound were very much annoyed, 94% of the respondents were not annoyed at all as Table (2) represents, and then the preference was 96%. While 13.72% of the respondents to the Irbid survey who heard it were very much annoyed, and 71.14% of the respondents were not annoyed at all as Table (2) represents and then the preference was 71.14%. These observed rates are somehow more than those reported by Al-Harthy (2006) for Muscat city observed 85.2%, and then the preference rate was 92.5%. Many sounds in Figure (1) and Figure (2) such as big cars (trucks), garbage cars and excavation and construction works, had a high observed rate and the lowest preference rate. Other lower preference rate sound sources were planes and water supply engines in both figures, the same results were obtained by Al-Harthy (2006). The observed rate and preference rate of normal cars sound were 89.2% and 24.8% in Zarqa sample *vs* 85.14% and 26.86% in Irbid sample. Moreover, respondents to the Zarqa and Irbid social surveys, preferred hearing of birds sound, 86% and 77.14%, respectively.

In response to Q4, Table (2) shows the degree of annoyance in Zarqa and Irbid city. In general, the Table points out that the sound of excavation and construction works was the most annoying sound in both Zarqa and Irbid, and that over 77% of the respondents to the Zarqa survey and over 82% of the respondents to the Irbid survey were very much annoyed, the second rank was the sound of big cars (trucks) which annoyed 66% of the respondents to the Zarqa survey *vs* 69.43% of the respondents to the Irbid survey. 52.8% of the Zarqa respondents and 44% of the Irbid respondents who heard normal cars sound were a little annoyed, followed by TV, stereo and music sound, 38.4% in Zarqa and 32.57% in Irbid. Most of the Zarqa and Irbid respondents were pleased and not annoyed at all with birds and azan sounds (where respondents to the Zarqa survey had a slight advantage in this point). Also, the results show that the percentage of people feeling moderately annoyed by the garbage car sound are greater than 30% in Zarqa sample and greater than 31% in Irbid sample, the second rank was the sound of water supply engines in Zarqa sample 28.4% and the sound of planes in Irbid sample 29.14%.

The study of Zarqa social survey revealed in relation to gender, education level, age (years) and employment state that unemployed literate females within the age of >53 years old were more likely to consider big cars very much annoying as compared to literate males. Respondents of

age between 28-40 and >53 years old, unemployed respondents and housewife respondents considered the sounds of TV, stereo and music moderately annoying, while the rest of the categories considered these sounds as a little annoying sounds. Student respondents (27.19%) were a little annoyed with parties' sounds, while the rest were very much annoyed with parties' sounds. There were no significant differences between males and females in response to the sounds of birds, azan and factories. Unemployed illiterate males within the age of >53 years old were more likely to consider normal cars as a little annoying as compared to females. Illiterate males were more likely to consider planes very much annoying compared to female respondents.

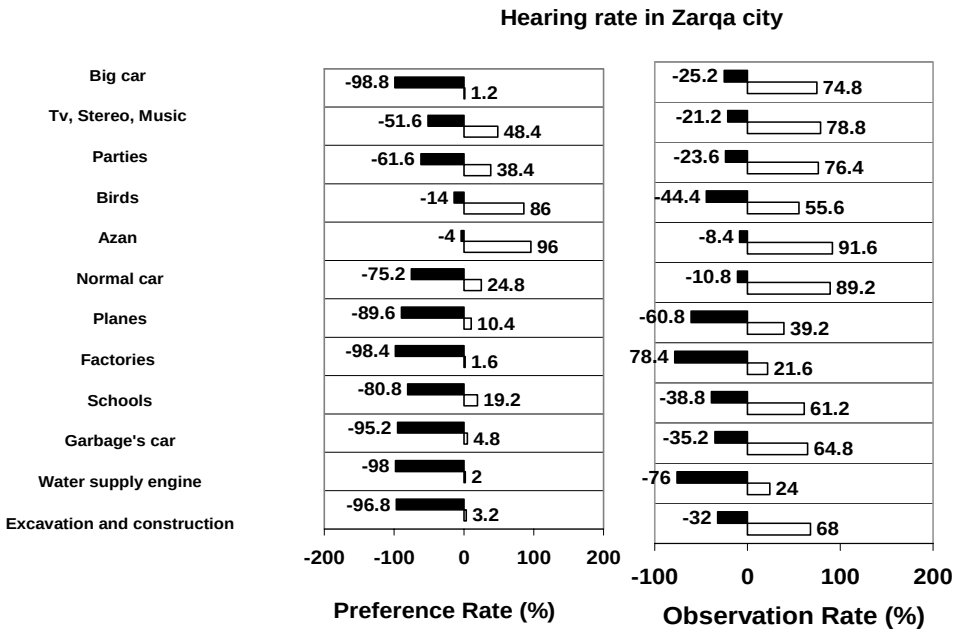

Figure (1): Observation and preference rate in Zarqa city.

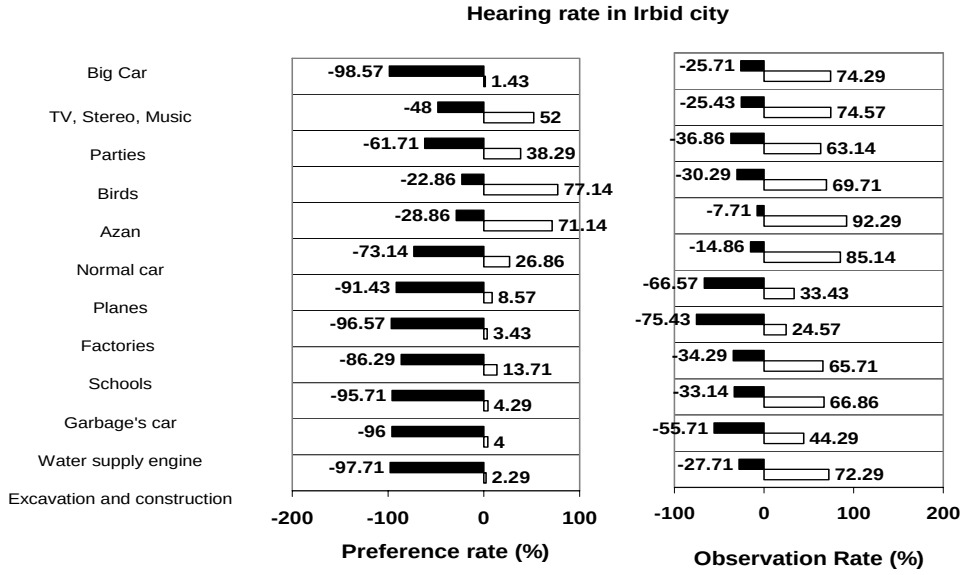

Figure (2): Observation and preference rate in Irbid city.

Table (2): Degree of annoyance by noise among the general public.

Noise source	Respondents, %							
	Not annoyed at all		A little annoyed		Moderately annoyed		Very much annoyed	
	Zarqa	Irbid	Zarqa	Irbid	Zarqa	Irbid	Zarqa	Irbid
Big cars (trucks)	2.40	2.00	9.60	9.14	22.00	19.43	66.00	69.43
TV, Stereo, Music	18.80	25.14	38.40	32.57	24.40	24.57	18.40	17.71
Parties	14.80	16.86	26.00	30.00	22.00	24.00	37.20	29.14
Birds	88.80	74.86	8.00	9.14	2.00	4.86	1.20	11.14
Azan	94.00	71.14	3.20	7.71	1.20	7.43	1.60	13.72
Normal cars	27.20	25.71	52.80	44.00	17.60	18.00	2.40	12.29
Planes	8.00	8.57	22.80	10.57	27.60	29.14	41.61	51.71
Factories	5.60	6.57	10.00	6.57	23.60	21.43	60.80	65.43
Schools	14.00	12.00	34.80	28.86	25.20	26.00	26.00	33.14
Garbage cars	6.80	4.86	20.00	16.29	30.40	31.43	42.80	47.42
Water supply engines	6.80	4.00	12.80	13.43	28.40	26.57	52.00	56.00
Excavation and construction works	1.60	1.43	4.40	4.00	16.40	12.00	77.60	82.57

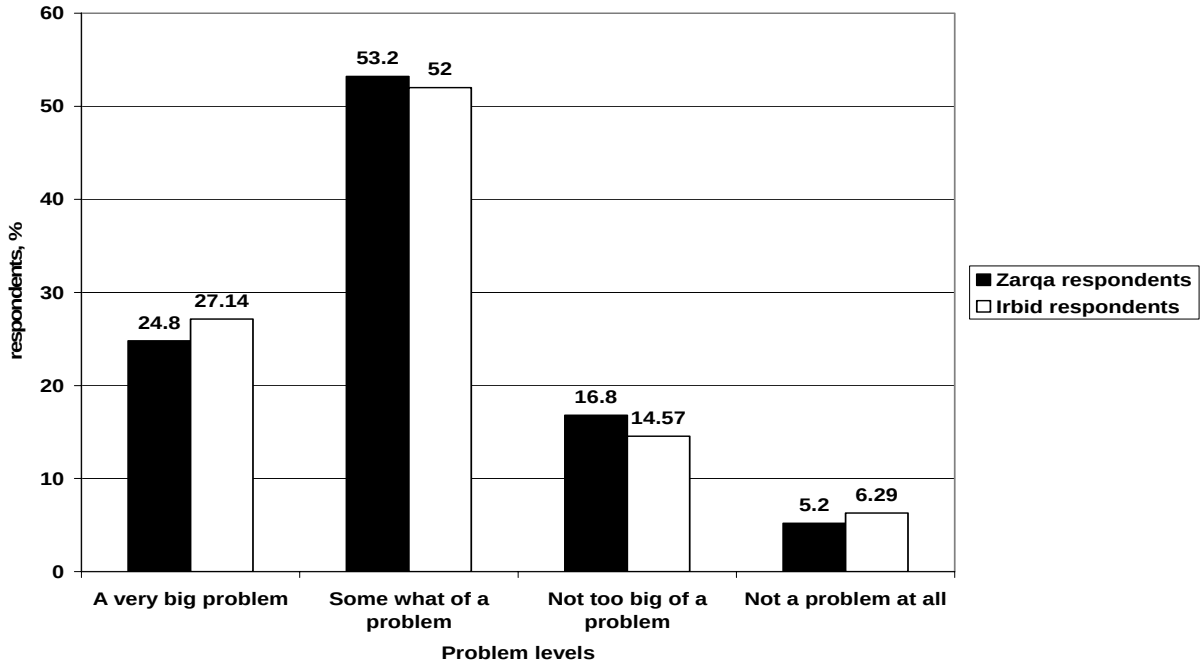

Figure (3): The size of the problem resulting from noise among the general public.

In Irbid social survey, the results revealed that unemployed illiterate females within the age of 46-61 years old were more likely to consider big cars very much annoying. No significant differences between males and females were found in response to factories, garbage cars, water supply engines and excavation and construction works sounds. Respondents of age between 30-45, 46-61 and >61 years old, and employee respondents considered TV, stereo and music moderately annoying sounds, while unemployed respondents considered them very much annoying sounds, the rest of the categories considered TV, stereo and music as a little annoying sounds. Female

respondents, literate respondents and respondents between 14-29 years old, and student respondents were a little annoyed with parties' sounds, while the rest of the respondents were very much annoyed with parties' sounds. There were no significant differences between males and females in response to birds and azan sounds, where females had a slight advantage in this point. Student female respondents within the age of 14-29 years old were more likely to consider normal cars as a little annoying as compared to the student male respondents.

Table (3): The size of the problem resulting from noise in relation to gender, education level, age and employment state.
(Respondents, %)

City	Problem level	Gender		Education		Age (years)				Employment state				
		Male	**Female**	**Literate**	**Illiterate**	**15-27**	**28-40**	**41-53**	**>53**	**Student**	**Employee**	**Unemployed**	**Housewife**	**Other**
Zarqa	A very big problem	24.24	25.42	26.32	9.09	29.73	20.00	12.50	20.00	28.95	25.23	00.00	00.00	10.00
	Some what of a problem	54.55	51.69	52.63	59.09	50.68	56.67	59.38	50.00	50.00	54.05	66.67	66.67	60.00
	Not too big of a problem	17.42	16.11	17.10	13.64	14.18	18.33	21.87	30.00	14.91	18.02	33.33	16.67	20.00
	Not a problem at all	3.79	6.78	3.95	18.18	5.41	5.00	6.25	00.00	6.14	2.70	00.00	16.66	10.00
		Male	**Female**	**Literate**	**Illiterate**	**14-29**	**30-45**	**46-61**	**>61**	**Student**	**Employee**	**Unemployed**	**Housewife**	**Other**
Irbid	A very big problem	26.87	27.31	26.32	37.04	25.00	23.14	41.67	00.00	21.97	39.73	37.50	33.33	29.03
	Some what of a problem	50.00	53.24	52.32	48.15	53.36	46.43	45.83	100.00	55.61	43.48	25.00	53.33	51.61
	Not too big of a problem	14.93	14.35	15.48	3.70	16.42	10.71	4.17	00.00	17.04	8.22	12.50	6.67	16.13
	Not a problem at all	8.21	5.09	5.88	11.11	5.22	10.71	8.33	00.00	5.38	8.22	25.00	6.67	3.23

In reaction to Q5, Figure (3) shows how big the problem resulting from the noise is, among the general public people in Zarqa and Irbid sample classified into more than one category, their opinion differed from one part to another, but we can notice that most of respondents to the Zarqa and Irbid social survey thought that the noise pollution causes some what of a problem 53.2% and 52%, respectively. And the part who thought that the noise pollution doesn't cause a problem at all was the minority; only 5.2% of respondents to the Zarqa survey *vs* 6.29% of respondents to the Irbid survey. 24.8% in Zarqa sample and 27.14% in Irbid sample think that the noise causes a very big problem.

The results of Zarqa survey in relation to gender, education level, age (years) and employment state shown in Table (3) show that most of males and females said that the noise pollution causes some what of a problem (where males had a slight advantage in this opinion) 54.55% and 51.69%, respectively. Illiterate respondents, respondents of age between 41-53 years old and housewife respondents were more likely to consider that noise causes some what of a problem as compared to other respondent categories. Student respondents and respondents between 15-27 years old thought that noise pollution causes a very big problem more than the other categories: 28.95% and 29.73%, respectively. While housewife respondents and illiterate respondents were the most categories that thought noise pollution is not a problem at all: 16.66% and 18.18%, respectively. While the results of Irbid survey shown also in Table (3) show that most of males and females saw that the noise pollution causes some what of a problem, the same result of Zarqa survey, but here females had a slight advantage 53.24% and 50%, respectively.

In response to Q6, Figure (4) shows the different negative effects resulting from the exposure to noise ranging from sleep interference to interference with listening to TV and radio, to activity disturbance and loss of concentration which had the highest value in Zarqa sample and Irbid sample: 75.6% and 78.57%, respectively, and also the effect on ability to work.

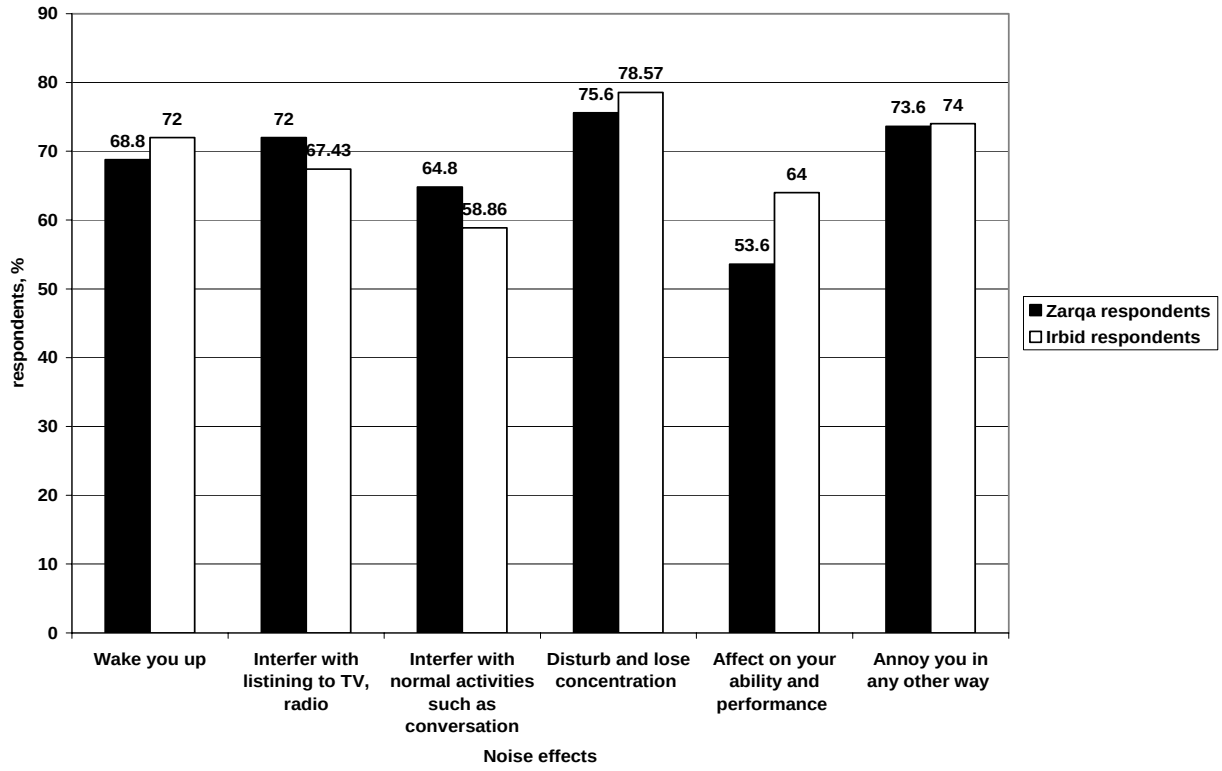

Figure (4): Noise effects among the general public.

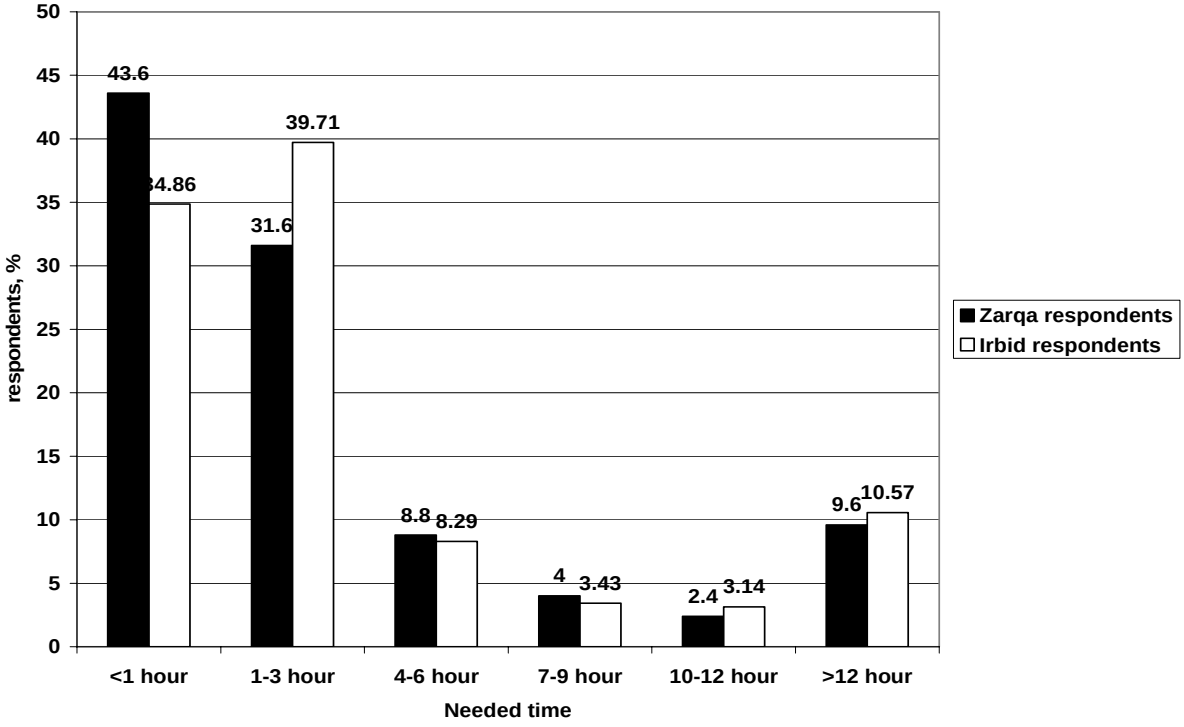

Figure (5): Needed hours to cope with the noise among the general public.

Table (4): Needed hours in relation to gender, education level, age and employment state. (Respondents, %)

City	Needed time	Gender		Education		Age (years)				Employment state				
		Male	**Female**	**Literate**	**Illiterate**	**15-27**	**28-40**	**41-53**	**>53**	**Student**	**Employee**	**Unemployed**	**Housewife**	**Other**
Zarqa	<1 hour	43.94	43.22	42.54	54.54	40.54	46.67	50.00	50.00	37.72	47.75	66.67	50.00	50.00
	1-3 hour	31.06	32.20	32.02	27.27	31.08	31.67	31.25	40.00	31.58	31.53	33.33	25.00	40.00
	4-6 hour	6.82	11.02	8.33	13.64	10.81	3.33	12.50	00.00	12.28	4.50	00.00	00.00	00.00
	7-9 hour	5.30	2.54	4.39	00.00	5.41	1.67	3.13	00.00	5.26	2.70	00.00	00.00	10.00
	10-12 hour	3.03	1.70	2.63	00.00	2.70	3.33	00.00	00.00	2.63	2.70	00.00	00.00	00.00
	>12 hour	9.85	9.32	10.09	4.55	9.46	13.33	3.12	10.00	10.53	10.82	00.00	00.00	00.00
		Male	**Female**	**Literate**	**Illiterate**	**14-29**	**30-45**	**46-61**	**>61**	**Student**	**Employee**	**Unemployed**	**Housewife**	**Other**
Irbid	<1 hour	37.31	33.33	35.91	22.22	32.84	46.43	33.33	00.00	32.29	45.21	37.50	33.33	29.03
	1-3 hour	42.54	37.96	38.39	55.55	38.06	41.07	54.17	50.00	36.32	41.10	37.50	46.67	58.06
	4-6 hour	11.94	6.02	8.98	00.00	8.96	5.36	4.17	50.00	9.42	4.11	12.50	00.00	12.90
	7-9 hour	0.75	5.09	3.10	7.41	3.36	3.57	4.17	00.00	3.59	2.74	00.00	13.33	00.00
	10-12 hour	2.99	3.24	3.10	3.70	4.10	00.00	00.00	00.00	4.48	1.37	00.00	00.00	00.00
	>12 hour	4.48	14.35	10.53	11.11	12.69	3.57	4.17	00.00	13.90	5.48	12.50	6.67	00.00

The results of the two social surveys in relation to gender, education level, age (years) and employment state show that females came first in finding that noise makes different effects compared to males except when noise disturbs and lets people lose concentration and when noise affects the ability to work, where males had a slight advantage. We noticed that respondents to the Zarqa survey within the age >53 years old were more affected by noise, especially on sleep interference and 100% said that noise wakes them up, and unemployed respondents came first in finding that noise affects the ability and performance in work. Respondents to the Irbid survey within the age >61 years old were the least category that said that noise interferes with sleep and wakes them up, where housewife respondents came first in finding that noise interferes with sleep and interferes with listening to TV and radio.

Figure (5) and Table (4) show the needed hours to cope with noise; the results of Q7. The figure points out that 43.6% of the respondents to the Zarqa social survey and 34.86% of the respondents to the Irbid social survey need <1hr to cope with noise. 31.6% of respondents to the Zarqa survey and 39.71% of respondents to the Irbid survey need 1-3hrs to cope with noise. These results give us an indication that people in both cities can not cope with noise instantly which makes the noise even a big problem. In Table (4) for the same question we can see that males and females in Zarqa city showed <1hr need to cope with noise, while males and females in Irbid city showed 1-3hrs need to cope with noise, and no significant differences were found between male and female respondents to the Zarqa and Irbid social surveys. Respondents to the Zarqa survey between 28-40 years old are the most category which needs 10-12hrs and >12hrs to cope with noise, unemployed respondents thought <1hr need to cope with noise more than the rest (66.67%). Student respondents to the Irbid survey were the most category with 10-12hrs to cope with noise, female respondents were the most category with >12hrs to cope with noise, respondents within the age of 30-45 years old thought <1hr need to cope with noise more than the rest 46.34%.

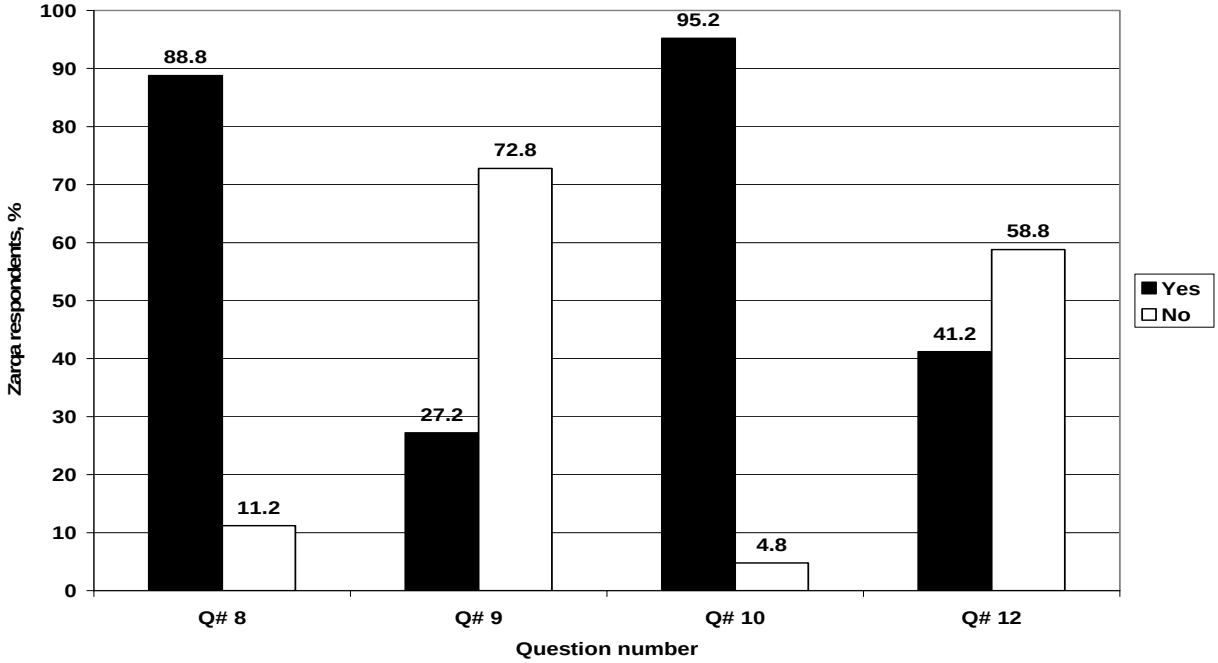

Figure (6): Outcome of Q# 8, 9, 10 and 12 among the general public for Zarqa survey.

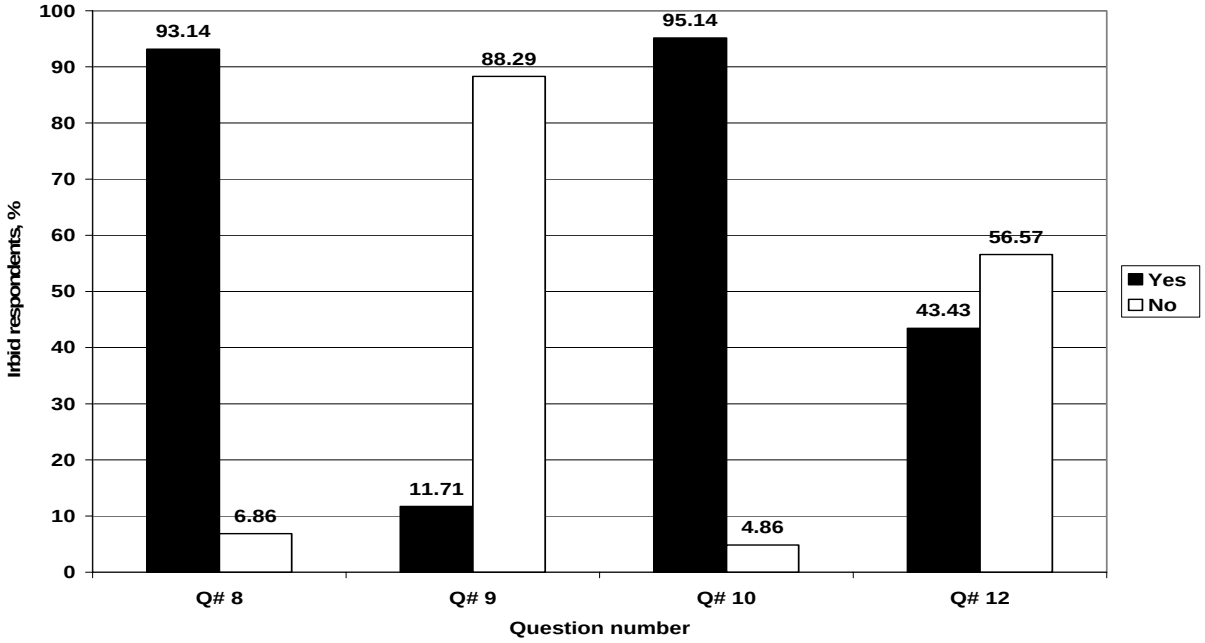

Figure (7): Outcome of Q# 8, 9, 10 and 12 among the general public for Irbid survey.

Table (5): Outcome of the same questions in relation to gender, education level, age (years) and employment state (Respondents, %).

City	Question #	Answer	Gender		Education		Age (years)				Employment state				
			Male	**Female**	**Literate**	**Illiterate**	**15-27**	**28-40**	**41-53**	**>53**	**Student**	**Employee**	**Unemployed**	**Housewife**	**Other**
Zarqa	8	Yes	88.64	88.98	89.47	81.82	87.84	88.33	93.75	90.00	87.72	90.99	100.00	83.33	80.00
		No	11.36	11.02	10.53	18.18	12.16	11.67	6.25	10.00	12.28	9.01	00.00	16.67	20.00
	9	Yes	35.61	17.80	25.44	45.45	21.62	26.67	46.88	50.00	24.56	25.23	100.00	41.67	40.00
		No	64.39	82.20	74.56	54.55	78.38	73.33	53.12	50.00	75.44	74.77	00.00	58.33	60.00
	10	Yes	92.42	98.31	96.05	86.36	95.95	93.33	96.88	90.00	96.49	94.59	100.00	100.00	80.00
		No	7.58	1.69	3.95	13.64	4.05	6.67	3.12	10.00	3.51	5.41	00.00	00.00	20.00
	12	Yes	46.97	34.75	41.67	36.36	38.51	50.00	40.62	30.00	35.09	46.85	33.33	33.33	60.00
		No	53.03	65.25	58.33	63.64	61.49	50.00	59.38	70.00	64.91	53.15	66.67	66.67	40.00
			Male	**Female**	**Literate**	**Illiterate**	**14-29**	**30-45**	**46-61**	**>61**	**Student**	**Employee**	**Unemployed**	**Housewife**	**Other**
Irbid	8	Yes	91.79	93.98	93.81	85.19	92.91	94.64	91.67	100.00	93.27	94.52	87.50	86.67	93.55
		No	8.21	6.02	6.19	14.81	7.09	5.36	8.33	00.00	6.73	5.48	12.50	13.33	6.45
	9	Yes	13.43	10.65	11.15	18.52	11.57	12.50	12.50	00.00	11.66	12.33	12.50	6.67	12.90
		No	86.57	89.35	88.85	81.48	88.34	87.50	87.50	100.00	88.34	87.67	87.50	93.33	87.10
	10	Yes	91.04	97.69	96.59	77.78	97.01	92.86	79.17	100.00	97.31	94.52	75.00	86.67	90.32
		No	8.96	2.31	3.41	22.22	2.99	7.14	20.83	00.00	2.69	5.48	25.00	13.33	9.68
	12	Yes	50.75	38.89	41.80	62.96	38.43	62.50	50.00	100.00	33.63	58.90	62.50	66.67	61.29
		No	49.25	61.11	87.04	37.04	61.57	37.50	50.00	00.00	66.37	41.10	37.50	33.33	38.71

Figures (6) and (7) show the outcome of Q# 8, 9, 10 and 12 among the general public for Zarqa and Irbid survey, respectively, while Table (5) shows the outcome of the same questions in relation to gender, education level, age (years) and employment state. The results of Q8 shown in these figures revealed that the concern about health effects attributed to noise was higher among respondents in the Irbid sample than in the Zarqa sample. Residents of Irbid city were more often afraid that their health would be affected by noise 93.14% *vs* 88.8% in the Zarqa sample, these values are somehow less than those reported for Amman. 94.6% of respondents to the Amman social survey carried out by Jamrah (2006) thought that noise can result in health impacts. For the same question, Table (5) shows that literate respondents to the Zarqa survey were more afraid that their health would be affected by noise compared to illiterate respondents, and unemployed people were the most category that thought the noise has a negative effect on their health, followed by the respondents between 41-53 years old. Also from the same Table, respondents to the Irbid survey within the age >61 years old were most category that thought the noise has a negative effect on their health, followed by the respondents between 30-45 years old, and illiterate respondents were the most category that thought the noise does not have a negative

effect on their health. The study in the two cities revealed no significant differences between males and females in response, and showed that the old generation is more aware of the effects of noise pollution than the newer generation.

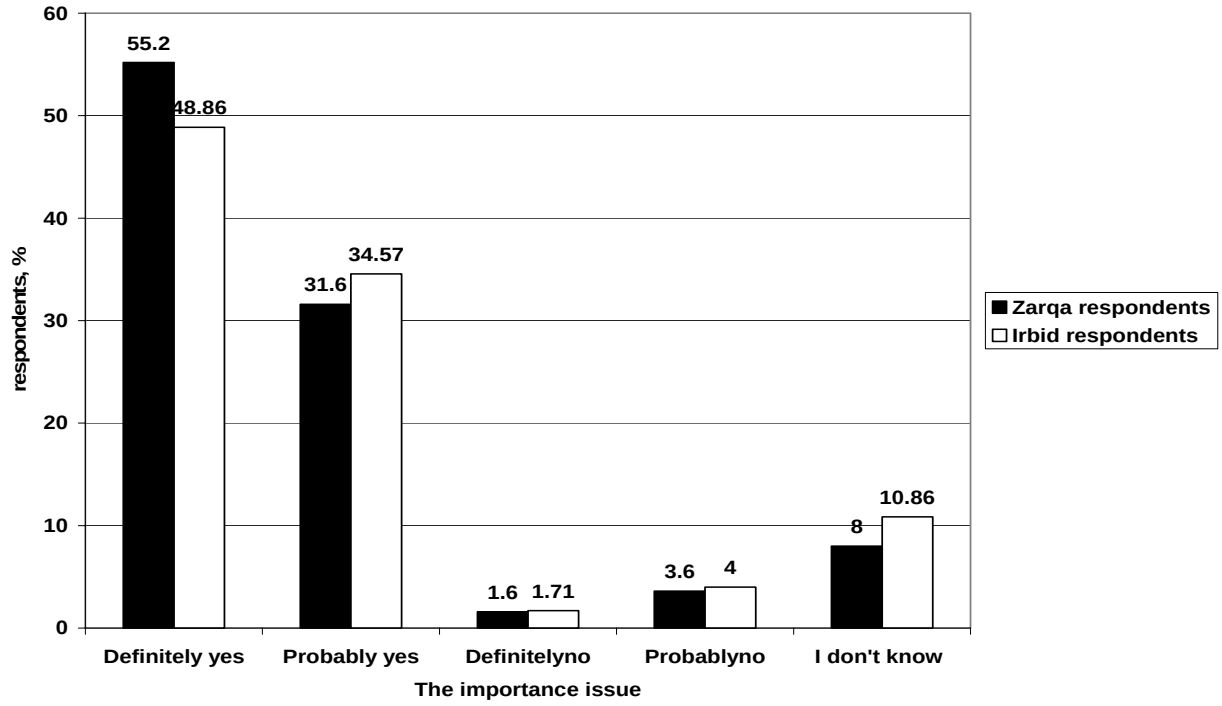

Figure (8): The extent to consider noise pollution an important issue among the general public.

The results of Q9 shown in Figure (4) and Figure (5) point out that people who didn't suffer any hearing-related problems caused by the noise were more than those who suffered from the noise in both Zarqa and Irbid city. We can notice from Table (5) that male respondents to the Zarqa survey who suffered any hearing-related problems were as twice the females who suffered from the noise, while male respondents to the Irbid survey said that they suffered hearing-related problems caused by noise in a higher percentage than females said: 13.43% *vs* 10.65%.

Many hearing-related problems caused by the noise were mentioned by the respondents to Zarqa and Irbid social surveys:

1- Tinnitus (Ringing in the ears).
2- Temporary hearing loss.
3- Pain and disturbance in the ears.
4- Weakness in hearing.
5- Myringotomy (Incision into the ear tympanic membrane).
6- Inability to hear the low sounds and inability to distinguish sounds.
7- Otilis (Inflammation of the ears).
8- Partial deafness.
9- Deafness and hearing loss.
10- Pressure on ears.

In response to Q10, the results shown in Figures (6) and (7) indicated that most of respondents to the Zarqa and Irbid surveys considered the noise an environmental pollutant and environmental nuisance, which reflects the public awareness to this important issue. Table (5) for the same question points that in both surveys females have higher awareness than males about noise issue.

Table (6): The extent to consider noise pollution an important issue in relation to gender, education level, age and employment state.
(Respondents, %)

City	Issue importance	Gender		Education		Age (years)				Employment state				
		Male	**Female**	**Literate**	**Illiterate**	**15-27**	**28-40**	**41-53**	**>53**	**Student**	**Employee**	**Unemployed**	**Housewife**	**Other**
Zarqa	Definitely yes	49.24	61.86	56.58	40.91	54.73	56.67	62.50	30.00	55.26	54.95	66.67	66.67	40.00
	Probably yes	37.88	24.58	31.58	31.82	31.76	28.33	28.13	60.00	28.95	32.43	33.33	25.00	60.00
	Definitely no	3.03	00.00	0.88	9.09	0.68	3.33	3.13	00.00	0.88	2.70	00.00	00.00	00.00
	Probably no	2.27	5.08	3.95	00.00	4.05	5.00	00.00	00.00	5.26	2.70	00.00	00.00	00.00
	I don't know	7.58	8.47	7.02	18.18	8.78	6.67	6.25	10.00	9.65	7.21	00.00	8.33	00.00
		Male	**Female**	**Literate**	**Illiterate**	**14-29**	**30-45**	**46-61**	**>61**	**Student**	**Employee**	**Unemployed**	**Housewife**	**Other**
Irbid	Definitely yes	50.00	48.15	49.32	44.44	49.63	42.86	54.17	50.00	51.57	47.95	37.50	53.33	32.26
	Probably yes	35.82	33.80	35.60	22.22	35.07	35.71	25.00	50.00	33.18	38.36	25.00	20.00	45.16
	Definitely no	0.75	2.31	1.86	00.00	1.49	3.57	00.00	00.00	0.45	2.74	12.50	6.67	3.23
	Probably no	3.73	4.17	4.02	3.70	4.10	3.57	4.17	00.00	4.04	4.11	00.00	6.67	3.23
	I don't know	9.70	11.57	9.29	29.63	9.70	14.29	16.67	00.00	10.76	6.85	25.00	13.33	16.13

Results of Q11 presented in Figure (8) show the extent to consider noise pollution an important issue among the general public. The Figure reveals that the concern about the noise issue was high among respondents to the Zarqa and Irbid social surveys, about half of the respondents thought that noise is definitely an important issue. Only 1.6% of respondents to the Zarqa survey and 1.17% of respondents to Irbid survey thought that noise is definitely not an important issue. The results in Table (6) in relation to gender point out that the concern about noise issue was higher among female respondents to the Zarqa survey as compared to male respondents, more than 60% of females said that the noise is definitely an important issue; while 49.24% of males had the same opinion. Also, the results of Irbid survey in Table (6) point out that the concern about the noise issue was higher among female and male respondents, where males had a slight advantage.

In reaction to Q12, the results in Figures (6) and (7) point out that people were divided between who agree and disagree that changing their place of living is a solution to the noise with a slight advantage to the disagreeing people in both Zarqa and Irbid social surveys, while the results of Amman survey by Jamrah (2006) revealed that most of people agree with moving their place of residence because of noise. Table (5) for the same question mentions that literate male respondents to the Zarqa survey within the age of 28-40 years old are more willing to move their place of residence due to noise, while illiterate male respondents to Irbid survey within the age >61 years old are most willing to move their place of residence due to noise. It is interesting to note that the group of literate male respondents to the Amman social survey within the age group of 35-55 years old are most willing to move their place of residence due to noise (Jamrah, 2006).

Noise Measurements in Zarqa and Irbid

Table 7 and Table 8 represent the mean noise measurements L10, L50, L90 and LA_{eq}, resulting from the exposure to the selected sources during day time and night time in Zarqa and Irbid city, respectively. As expected, the Tables represent a gradual decrease in sound levels. L10, L50 and L90 are detectable, becoming more pronounced in night time.

Table (7): Measurements of the mean noise levels; L10, L50, L90 and LA_{eq} in day time and night time for Zarqa city.

Noise sources	Zone description	Day – time dB(A)				Night – time dB(A)			
		L_{10}	L_{50}	L_{90}	L_{eq}	L_{10}	L_{50}	L_{90}	L_{eq}
Mosques	No nearby highways, car parks, quiet apartments, residential area, non – commercial public building area, small streets with light traffic volume.	81.5	67.1	54.5	74.8	81.0	65.1	50.0	74.3
Schools	No nearby highways, residential area, car parks, quiet apartments, streets with light traffic volume.	74.8	64.2	56.8	68.7	56.3	50.0	44.1	51.4
Celebration halls	Residential area, no nearby highways, car parks.	58.6	56.4	51.6	56.6	81.3	76.0	72.6	77.5
Construction and building works	Residential area, quiet apartments, no nearby highways, heavy equipment, trucks, dredges.	92.2	86.4	77.4	86.9	53.0	45.8	40.0	47.8
Commercial zone	Commercial public building area and residential area, workshops and simple handicrafts, busy streets, car parks, area of intense human activity.	75.0	72.7	67.7	72.3	66.6	63.0	56.5	62.6
Industrial zone	Residential area, non – commercial public building area, heavy industry and heavy equipment, busy streets with different types of cars; big cars and normal cars, noisy apartments.	88.0	80.3	73.0	83.1	78.4	71.1	60.2	73.6
Traffic noise	Residential area, highway streets with big cars, normal cars and trucks, large traffic volume, institutional buildings.	88.0	85.5	72.6	84.3	80.0	75.2	68.0	76.4

Table (8): Measurements of the mean noise levels; L10, L50, L90 and LA_{eq} in day time and night time for Irbid city.

Noise sources	**Zone description**	**Day – time dB(A)**				**Night – time dB(A)**			
		L_{10}	**L_{50}**	**L_{90}**	**L_{eq}**	**L_{10}**	**L_{50}**	**L_{90}**	**L_{eq}**
Mosques	No nearby highways, car parks, quiet apartments, residential area, non – commercial public building area, small streets with light traffic volume.	81.7	65.1	54.0	75.7	80.5	64.8	51.2	74.2
Schools	No nearby highways, residential area, car parks, quiet apartments, streets with light traffic volume.	76.0	66.7	56.4	69.9	56.2	48.0	42.0	50.4
Celebration halls	Residential area, no nearby highways, car parks.	58.4	56.8	52.8	56.0	81.3	76.0	72.6	77.5
Construction and building works	Residential area, quiet apartments, no nearby highways, heavy equipment, trucks, dredges.	91.2	85.1	76.9	85.9	50.0	46.9	41.3	46.6
Commercial zone	Commercial public building area and residential area, workshops and simple handicraft, busy streets, car parks, area of intense human activity.	74.4	70.4	65.3	70.8	66.8	61.0	54.2	62.4
Industrial zone	Residential area, non – commercial public building area, heavy industry and heavy equipment, busy streets with different types of cars; big cars and normal cars, noisy apartments.	83.9	80.0	70.0	80.1	76.1	70.9	61.1	72.2
Traffic noise	Residential area, highway streets with big cars, normal cars and trucks, large traffic volume, institutional buildings.	87.1	84.4	71.5	83.7	80.4	72.2	64.7	75.3

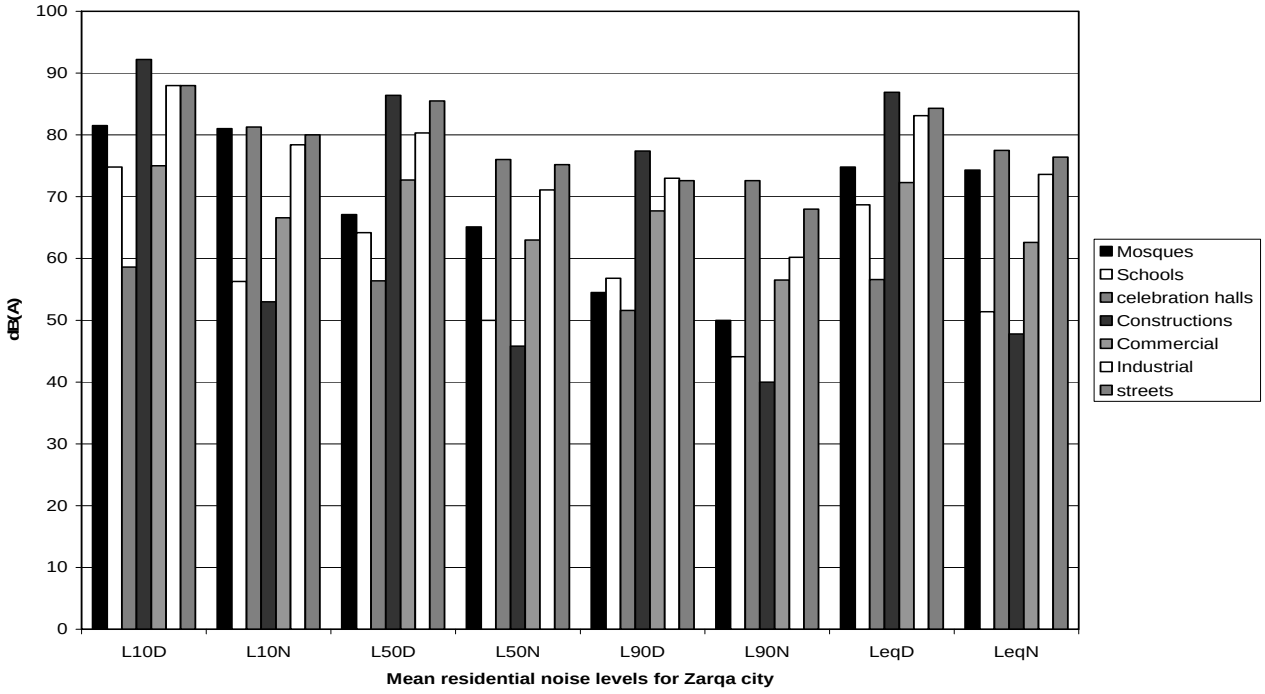

Figure (9): Mean residential noise levels for different noise sources in Zarqa city.

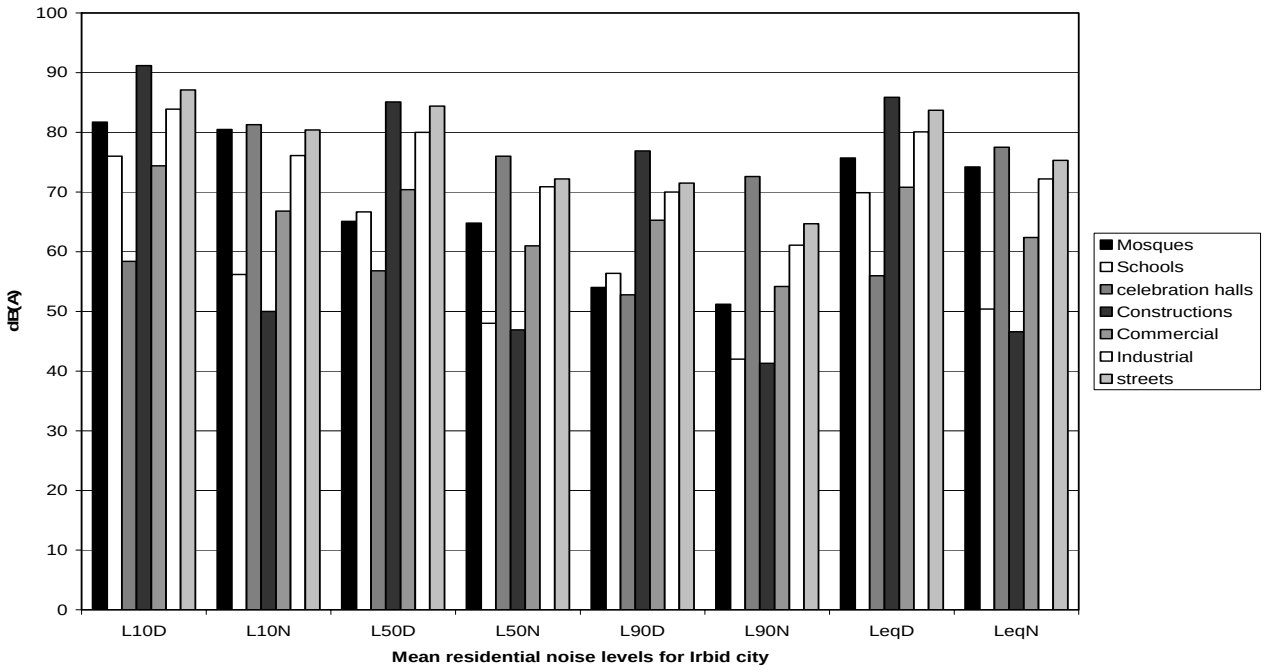

Figure (10): Mean residential noise levels for different noise sources in Irbid city.

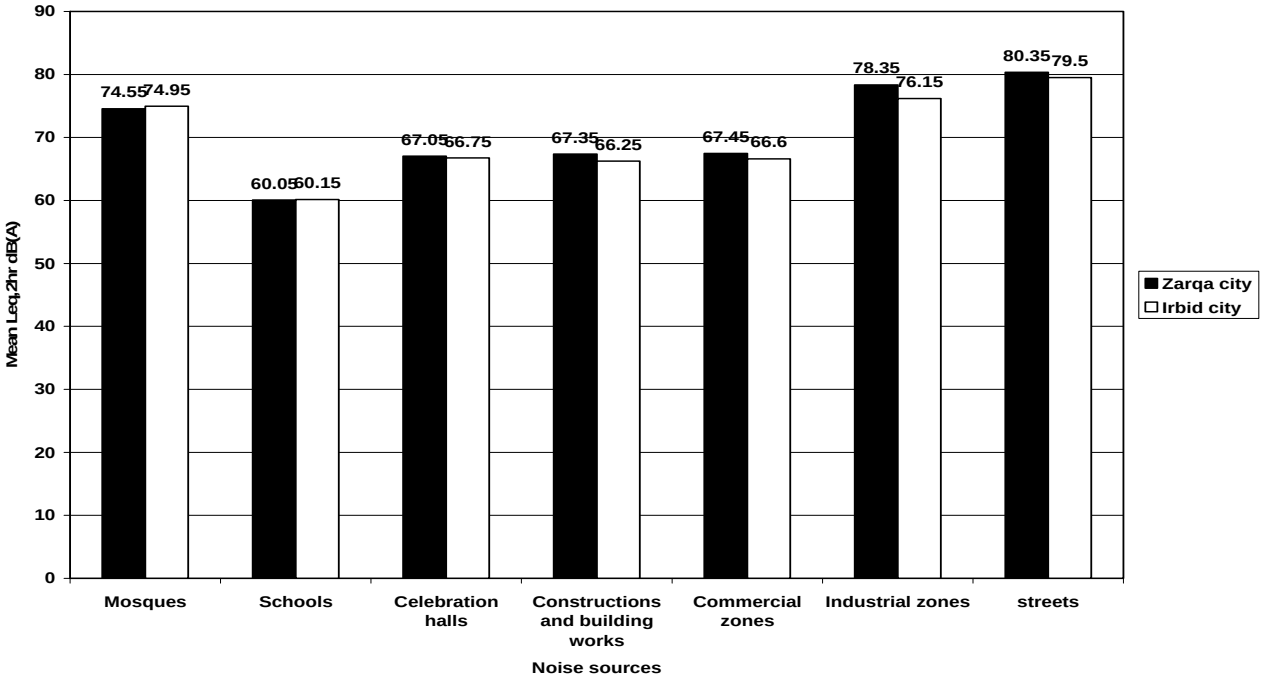

Figure (11): comparison of mean LA_{eq}, 2hr values per zone in Zarqa and Irbid.

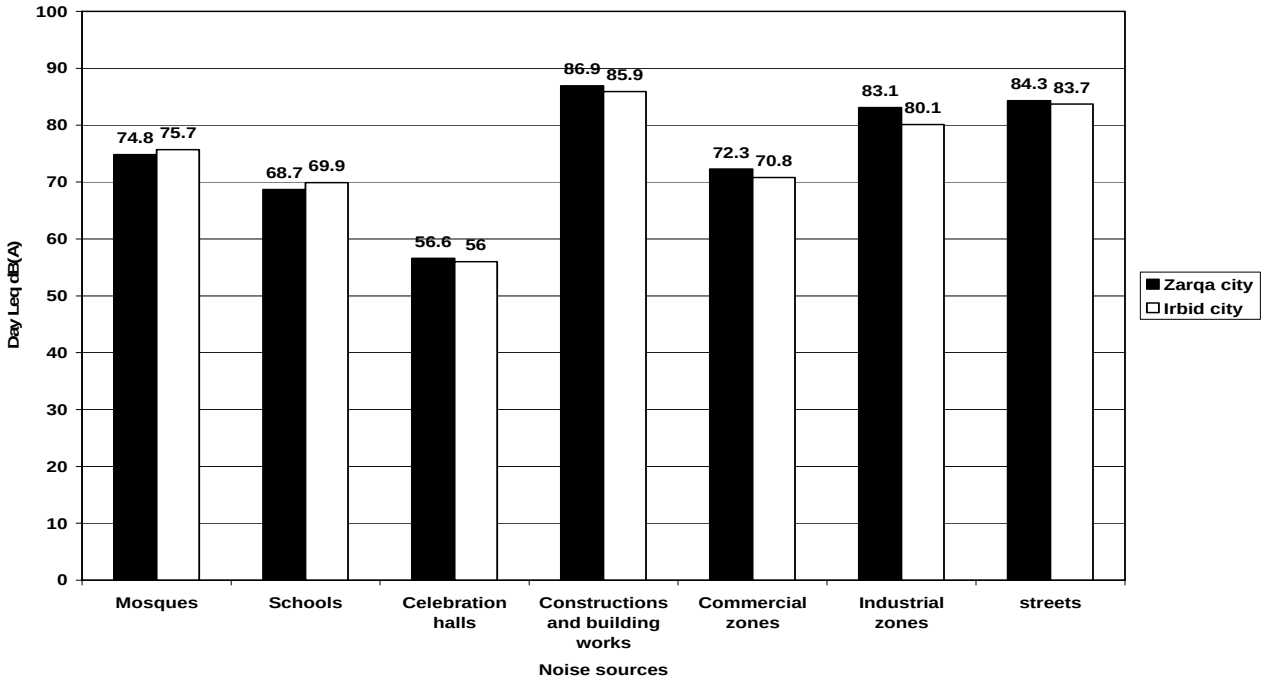

Figure (12): Comparison of measured day – time continuous equivalent noise levels, LA_{eq} in Zarqa and Irbid.

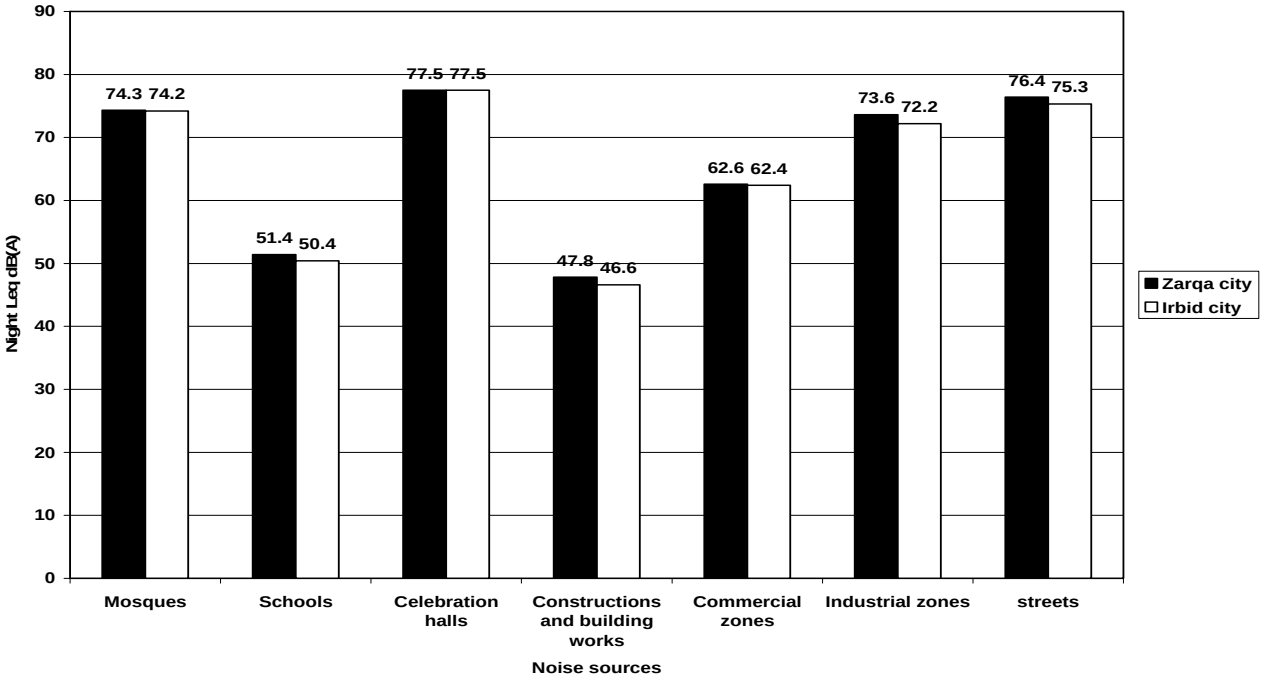

Figure (13): Comparison of measured night – time continuous equivalent noise levels, LA_{eq} in Zarqa and Irbid.

Table (9): The maximum permissible noise limits, in terms of equivalent continuous noise level dB(A), LAeq.d and LAeq.n for different areas set by the Ministry of Environment in 1997.

Region	Maximum limits dB(A)	
	Day time	Night time
Urban residential	60	50
Suburban residential	55	45
Rural residential	50	40
Residential area with some workshops, simple handicrafts and commercial area in the center of the city	65	55
Industrial areas (heavy industries)	75	65
Areas of education, hospitalization and worshipping	45	35

Figures 9 and 10 illustrate the mean residential noise levels L10, L50, L90 and LA_{eq} in day time and night time for different sources in Zarqa and Irbid, respectively. In day time L10, L50, L90 and LA_{eq} are higher than those in the day time for all the sources in Zarqa and Irbid except the sound from the celebration halls, LAeq.n in Zarqa and Irbid was 77.5 dB(A), LAeq.d was 56.6 and 56.0 dB(A) in Zarqa and Irbid, respectively. Due to the life style in these areas where no parties start at day time, a sound at night may be more annoying than during the day. Figure 11 shows the mean celebration halls noise level LA_{eq},2hrs for the two periods 67.05 and 66.75 dB(A) in Zarqa and Irbid, respectively. Digital audio players and sound amplifier devices might increase the volume of sound in the celebration halls. The noise level from celebration halls LA_{eq} difference between day time and night time in Zarqa and Irbid, was ~ 21 dB(A). Again from Figures 9 and 10 in day time the mean values of celebration halls noise levels L10, L50 and L90 for Zarqa city are 58.6, 56.4 and 51.6 dB(A), respectively. In Irbid the

corresponding values are 58.4, 56.8 and 52.8 dB(A). In night time an increase in noise level is detectable, L10, L50 and L90 being 81.3, 76.0 and 72.6 dB(A), respectively.

Zarqa city is some how noisier than Irbid city during both the day time and night time hours with a mean noise level LA_{eq},2hrs for the two periods that exceeds 74 dB(A) for mosques sound, 60 dB(A) for schools sound, 67 dB(A) for celebration halls sound, 67 dB(A) for construction and building works sound, 67 dB(A) for commercial zones sound, 78 dB(A) for industrial zones sound, 80 dB(A) for traffic sound as Figure 11 represents. We can notice from Figures 9 and 10 that in the six sources the construction and building works noise has a maximum value of noise levels L10, L50, L90 and LA_{eq} in day time in both Zarqa and Irbid, and the traffic noise has a maximum of noise levels L10, L50, L90 and LA_{eq} at night, also traffic noise levels in daytime were high, so the traffic noise was considered the major source of environmental noise pollution and annoyance.

Noise levels in LA_{eq} on the streets were higher on day and night time with a mean noise LA_{eq}, 2hr level for the two periods 80.35 and 79.5 dB(A) in Zarqa and Irbid, respectively (Fig.11). The reason for this was that noise from highway streets was further added to the noise levels on the streets.

There were a good agreement between measured values and results obtained by the survey carried out in Zarqa and Irbid; 66%, 42.8% and 52% of respondents to the Zarqa survey and 69.43%, 47.42% and 56% of respondents to the Irbid survey were very much annoyed with big cars, garbage cars and water supply engine cars, respectively.

As observed earlier, traffic noise level LA_{eq} was generally higher in the day time than it was in the night time: 84.3 dB(A) in Zarqa and 83.7 dB(A) in Irbid (Fig.12). Figure 13 reveals that the equivalent traffic noise levels of 76.4 dB(A) and 75.3 dB(A) are also high during night hours in Zarqa and Irbid , respectively. So this figure indicates that the problem of traffic noise is not only limited to day time, but continues throughout most of the hours of day and night in these cities. The noise levels LA_{eq} difference between day time and night time in Zarqa and Irbid, was 7.9 and 8.4 dB(A), respectively.

The LAeq.d and LAeq.n for traffic noise were higher than those set by Jordanian standards in Table 9. The LA_{eq} day time traffic noise level in Zarqa city is greater than the LA_{eq} day time noise level in Irbid by 0.6 dB(A) (Fig.12). Also, Figures 9 and 10 point out that in day time the mean values of traffic noise levels L10, L50 and L90 for Zarqa city are 88, 85.5 and 72.6 dB(A), respectively. In Irbid city the corresponding values are 87.1, 84.4 and 71.5 dB(A). At night, a decrease in noise level is detectable which is less pronounced in Zarqa than in Irbid, L10, L50 and L90 being 80, 75.2 and 68 dB(A) in Zarqa and 80.4, 72.2 and 64.7 dB(A) in Irbid. These differences can be explained by the differences in the nature of traffic in these cities.

From Tables 7 and 8, we can see that traffic noise level L10.d is about 3.7 dB(A) above LAeq.d, L50d is about 1.2 dB(A) above LAeq.d and L90.d is about 11.7 lower than LAeq.d in Zarqa. While in Irbid L10.d is about 3.4 dB(A) above LAeq.d, L50.d is about 0.7 dB(A) above LAeq.d and L90.d is about 12.2 lower than LAeq.d. These noise levels are higher than those reported for other cities in Italy and for Amman (Piccolo et al., 2004; Jamrah et al., 2006). Additionally, these noise levels are similar to those reported for other cities around the world in Kuwait, India and for Muscat (Koushki et al., 2006; Pandya, 2003; Al-Harthy, 2006).

Noise levels resulting from mosques in LAeq.d and LAeq.n with a mean noise LAeq, 2hr level for the two periods that exceeds 74 dB(A) (Fig.11) were higher in both Zarqa and Irbid. The agreement between measured noise level and the percentage obtained by the survey was poor: 94% and 71.14% of respondents to the Zarqa survey and Irbid survey, respectively were not annoyed at all with the azan sound. The inherent unpleasantness of sound causes annoyance. In addition, listeners attribute sound influences to annoyance; so that if listeners dislike the noise content, they are annoyed, and if the listeners like the noise content, they are not annoyed.

LAeq.d and LAeq.n (74.8 and 74.3 dB(A)) and (75.7 and 74.2 dB(A)) in Zarqa and Irbid, shown in Figures 12 and 13 were higher than LAeq.d and LAeq.n of Jordanian standard (Ministry of Environment, 1997); the standard presented in Table 9. Zarqa LAeq.d and LAeq.n values exceeded the maximum permissible limits by 29.8 dB(A) and 39.3 dB(A), while Irbid values exceeded the maximum permissible limits by 30.7 dB(A) and 39.2 dB(A).

The mosque noise levels LA_{eq} difference between day time and night time in Zarqa and Irbid was 0.5 and 1.5 dB(A), respectively (not a significant difference). Figure 12 shows that LA_{eq} day time mosque noise level in Irbid is greater than LA_{eq} day time noise level in Zarqa by 0.9 dB(A). Figures 9 and 10 illustrate that in day time the mean value of mosque noise levels L10, L50 and L90 for Zarqa city are 81.5, 67.1 and 54.5 dB(A), respectively. In Irbid, the corresponding values are 81.7, 65.1 and 54.0 dB(A). In this case there is no significant difference between day and night levels, and the decrease in statistical noise levels is not detectable in night time, L10, L50 and L90 being 81.0, 65.1 and 50.0 dB(A), respectively in Zarqa and 80.5, 64.8 and 51.2 dB(A) in Irbid. Again from Tables 7 and 8, mosque noise level L10.d is about 6.7 dB(A) above LAeq.d, L50.d is about 7.7 dB(A) lower than LAeq.d and L90.d is about 20.3 dB(A) lower than LAeq.d in Zarqa city. While in Irbid city L10.d is about 6 dB(A) above LAeq.d, L50.d is about 10.6 dB(A) lower than LAeq.d and L90.d is about 21.7 dB(A) lower than LAeq.d.

The higher LAeq.d and LAeq.n levels presented in Figures 12 and 13 of industrial zones with a mean noise LA_{eq}, 2hr level for the two periods 78.35 and 76.15 dB(A) in Zarqa and Irbid, respectively (Fig.11) are similar to those reported in the city of Curitiba, Brazil (Zanin et al., 2002).

There was a good agreement between measured values and the results obtained by the survey carried out in Zarqa and Irbid, 60.80% of the respondents to the Zarqa survey and 65.43% of the respondents to the Irbid survey were very much annoyed with factory noise.

Industrial noise levels LAeq.d and LAeq.n were higher than LAeq.d and LAeq.n of the Jordanian standard. The Jordanian standard (Ministry of Environment, 1997) recommends 75 dB(A) LA_{eq} in day time and 65 dB(A) LA_{eq} in night time; the standard presented in Table 9. In Zarqa city LAeq.d and LAeq.n values exceeded the maximum permissible limits by 8.1 dB(A) and 8.6 dB(A), while in Irbid the values exceeded the maximum permissible limits by 5.1 dB(A) and 7.2 dB(A).

The noise levels LA_{eq} difference between day time and night time in Zarqa and Irbid, was respectively 9.5 and 7.9 dB(A), the difference in LA_{eq} was somehow higher in Zarqa than in Irbid.

For Zarqa city, LAeq.d of industrial zones is 83.1 dB(A), while considering Irbid city, a decrease in industrial noise level is detectable 80.1 dB(A) as shown in Figure 12 indicating an extra noise of 3 dB(A). LAeq.n of industrial zones for Zarqa and Irbid, respectively 73.6 and 72.2 dB(A) as shown in Figure 13 indicate an extra noise of 1.4 dB(A). In day time the mean value of industrial noise levels L10, L50 and L90 for Zarqa are respectively 88, 80.3 and 73.0 dB(A). In Irbid the corresponding values are 83.9, 80.0 and 70.0 dB(A). Also in this case a decrease in noise levels is detectable in night time that is slightly more pronounced in Irbid than in Zarqa. L10, L50 and L90 were respectively 78.4, 71.1 and 60.2 dB(A) in Zarqa and 76.1, 70.9 and 61.1 in Irbid as shown in Figures 9 and 10.

Virtually in industrial sites the dominant noise source was motors of large vehicles and engines. In Zarqa city, therefore, the additional traffic volume produces in day time and in night time an extra noise. In industrial zones, noise level L10.d is about 4.9 dB(A) above LAeq.d, L50.d is about 2.8 dB(A) lower than LAeq.d and L90.d is about 10.1 dB(A) lower than LAeq.d in Zarqa city. While in Irbid L10.d is about 3.8 dB(A) above LAeq.d, L50.d is about 0.1 dB(A) lower than LAeq.d and L90.d is about 10.1 dB(A) lower than LAeq.d.

In commercial zones the area is surrounded by buildings (public and institutional buildings). Commercial noise in LA_{eq} was higher on day and night time, with a mean noise LA_{eq}, 2hr level for the two

periods 67.45 and 66.6 dB(A) in Zarqa and Irbid, respectively (Fig.11). LAeq.d and LAeq.n were (72.3 and 62.6 dB(A)) and (70.8 and 62.4 dB(A)) in Zarqa and Irbid, respectively, as shown in Figures 12 and 13. The presence of slow moving vehicles, low speed and honking of horns during traffic congestion periods lead to an increase in noise levels in commercial areas.

The noise levels LA_{eq} difference between daytime and night time in Zarqa and Irbid was respectively 9.7 and 8.4 dB(A).

Commercial noise levels LAeq.d and LAeq.n were higher than LAeq.d and LAeq.n of Jordan standards. The Jordan standards (Ministry of Environment, 1997) recommend 65 dB(A) LA_{eq} in day time and 55 dB(A) LA_{eq} in night time; the standard presented in Table 9. In Zarqa LAeq.d and LAeq.n values exceeded the maximum permissible limits by 7.3 dB(A) and 7.6 dB(A), while in Irbid values exceeded the maximum permissible limits by 5.8 dB(A) and 7.4 dB(A). Figures 12 and 13 reveal that the equivalent continuous noise level LA_{eq} in day time of commercial noise level in Zarqa is greater than the LAeq day time noise level in Irbid by 1.5 dB(A). Figures 9 and 10 present that in day time the mean values of commercial area noise levels, L10, L50 and L90 for Zarqa city are respectively 75.0, 72.7 and 67.7 dB(A). In Irbid the corresponding values are 74.4, 70.4 and 65.3 dB(A). In night time a decrease in noise level is detectable which is more pronounced in Irbid than in Zarqa; L10, L50 and L90 being respectively 66.6, 63.0 and 56.5 dB(A) in Zarqa and 66.8, 61.0 and 54.2 dB(A) in Irbid. The higher LA_{eq}, L10, L50 and L90 levels in Zarqa than in Irbid can be attributed to normally greater motor vehicle activity in this area.

We can observe from Tables 7 and 8 that commercial zone noise levels, L10.d is about 2.7 dB(A) above LAeq.d, L50.d is about 0.4 dB(A) above LAeq.d and L90.d is about 4.6 dB(A) lower than LAeq.d in Zarqa city. While in Irbid L10.d is about 3.6 dB(A) above LAeq.d, L50.d is about 0.4 dB(A) lower than LAeq.d and L90.d is about 5.5 dB(A) lower than LAeq.d. The schools noise level LAeq.d in Zarqa obtained was 68.7 dB(A) and 69.9 dB(A) in Irbid. During night, the levels LAeq.n decreased noticeably to 51.4 dB(A) for Zarqa and 50.4 dB(A) for Irbid, as can be checked in Figures 12 and 13. In day time the mean values of schools noise levels L10, L50 and L90 for Zarqa city are respectively 74.8, 64.2 and 56.8 dB(A). In Irbid city the corresponding values are 76.0, 66.7 and 56.4 dB(A). The noise levels LA_{eq} difference between day time and night time was higher in Zarqa and Irbid; respectively, 17.3 and 19.5 dB(A).

In night time a decrease in noise level is detectable, L10, L50 and L90 being respectively 56.3, 50.0 and 44.1 dB(A) in Zarqa and 56.2, 48.0 and 42.0 dB(A) in Irbid, as noticed in Figures 9 and 10. At night, there are no school activities, the main daily activities begin in the morning hours. This is reflected by a higher LA_{eq}, L10, L50 and L90 in day time.

We can observe that the LA_{eq} day time schools noise level in Irbid is greater than the LA_{eq} day time noise level in Zarqa by 1.2 dB(A). LAeq.d and LAeq.n of schools noise are higher than LAeq.d and LAeq.n of Jordan standard (Ministry of Environment, 1997); the standard presented in Table 9. In Zarqa LAeq.d and LAeq.n values exceeded the maximum permissible limits by 23.7 dB(A) and 16.4 dB(A), while in Irbid values exceeded the maximum permissible limits by 24.9 dB(A) and 15.4 dB(A).

The mean equivalent level, LA_{eq}, 2hr for the two periods of the schools noise was higher ~ 60 dB(A) in Zarqa and Irbid, as shown in Figure 11. There was a poor agreement between measured values and results obtained by the survey carried out in Zarqa and Irbid, a very low percentage of respondents were very much annoyed with schools noise. The reason can be attributed to the listeners; if listeners feel that they can control the noise source and tolerate the sound resulting from the source without causing any problems that disturb the normal activity, they are less likely annoyed by the noise.

It is observed that schools noise level L10.d is about 6.1 dB(A) above LAeq.d, L50.d is about 4.5 dB(A) lower than than LAeq.d and L90.d is about 11.9 dB(A) lower than LAeq.d in Zarqa city. While in Irbid L10.d is about 6.1 dB(A) above LAeq.d, L50.d is about 3.2 dB(A) lower than LAeq.d and L90.d is about 13.5 dB(A) lower than LAeq.d.

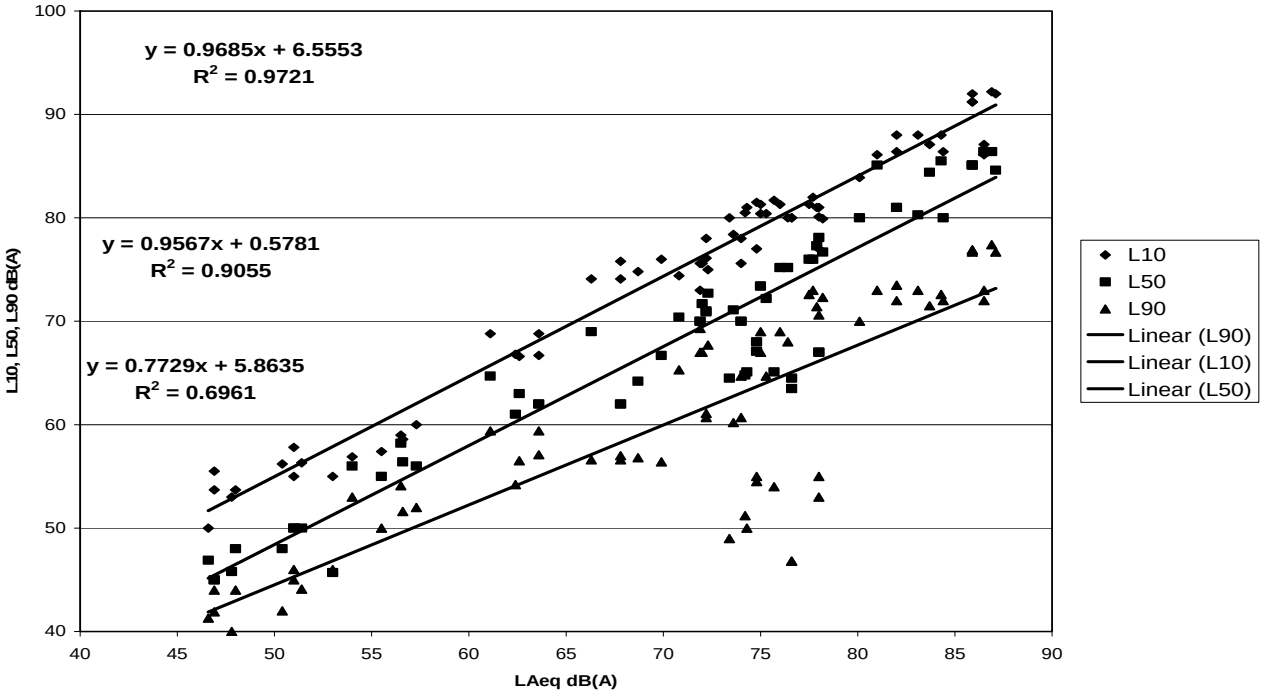

Figure (14): Linear relationships between measured percentile levels L10, L50, L90 and LA_{eq} in Zarqa city.

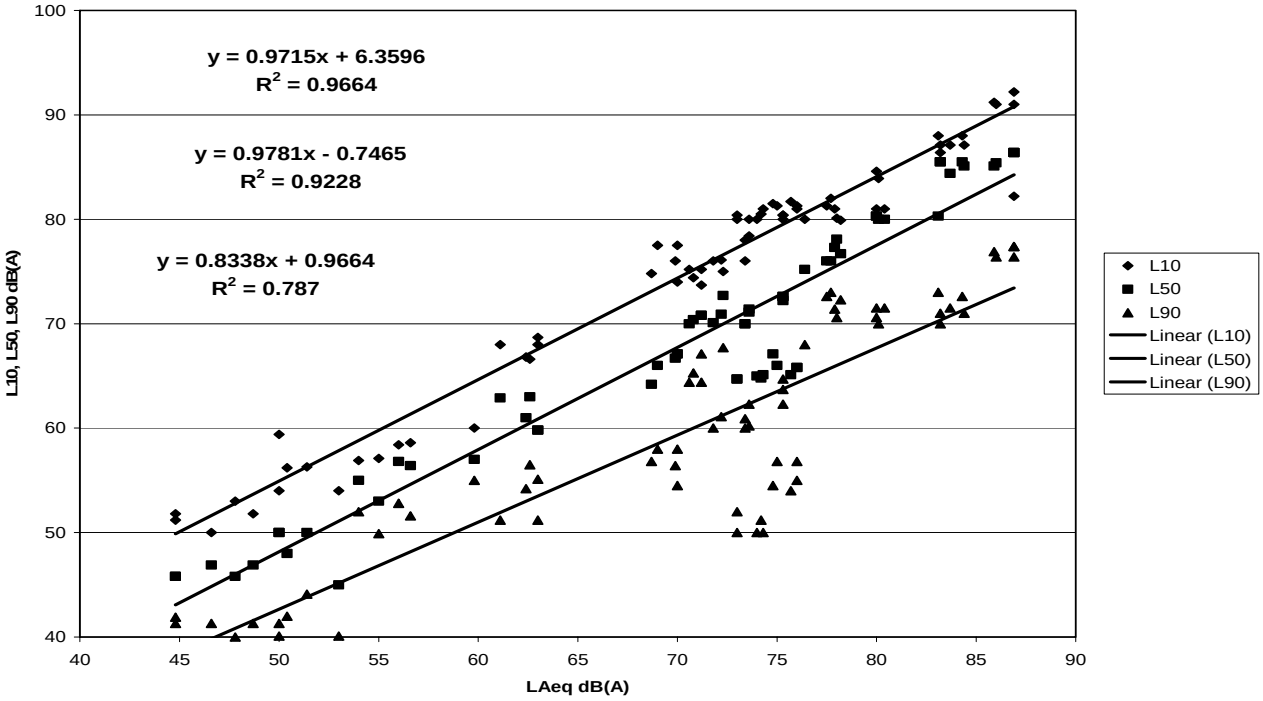

Figure (15): Linear relationships between measured percentile levels L10, L50, L90 and LA_{eq} in Irbid city.

The noise from construction and building machines and equipment (dredges, concrete mixers, concrete pumps and jackhammers) is quite different from that of traditional equipment. The construction machines have engines that produce a loud, fluctuating noise with varying frequencies that can propagate the sound for a long distance. The noise produced by these engines is particularly disturbing due to the wide variations in frequency and volume. Also a sound that fluctuates may be more annoying than one that does not. Noise levels in LA_{eq} at the construction sites were higher on day time in the two cities, LAeq.d in Zarqa was 86.9 dB(A) and 85.9 dB(A) in Irbid. During the night, the levels LAeq.n decreased noticeably, 47.8 and 46.6 dB(A) in Zarqa and Irbid, respectively (Figures 12 and 13). So the noise level LA_{eq} difference between day time and night time was higher in Zarqa and Irbid ~ 39 dB(A). As can be checked from Figures 9 and 10, in day time the mean values of construction noise levels L10, L50 and L90 for Zarqa city are respectively 92.2, 86.4 and 77.4. In Irbid the corresponding values are 91.2, 85.1 and 76.9. In night time a decrease in noise level is detectable, L10, L50 and L90 being respectively 53.0, 45.8 and 40.0 dB(A) for Zarqa and 50.0, 46.9 and 41.3 dB(A) for Irbid. Due to the life style in these areas with no constructions and building works during night time, and with heavy trucks and vehicles being limited during night, and these activities concentrated in day time, this is reflected by higher LA_{eq}, L10, L50 and L90 in day time.

The mean equivalent noise level, LA_{eq}, 2hr for the two periods at construction sites was higher, more than 66 dB(A) in Zarqa and Irbid (as shown in Figure 11). The agreement between measured noise level and the percentage obtained by the survey was good. 77.6% and 82.57% of the respondents to the Zarqa survey and Irbid survey respectively were very much annoyed. Also as can be checked from Tables 7 and 8, construction noise level L10.d is about 5.3 dB(A) above LAeq.d, L50.d is about 0.5 dB(A) lower than LAeq.d and L90.d is about 9.5 dB(A) lower than LAeq.d in Zarqa city. While in Irbid L10.d is about 5.3 dB(A) above LAeq.d, L50.d is about 0.8 dB(A) lower than LAeq.d and L90.d is about 9.0 dB(A) lower than LAeq.d. Also we can observe that the LA_{eq} day time construction and building works noise in Zarqa is greater than day time noise level in Irbid by 1.0 dB(A); not a significant difference.

In the paper by Zannin et al. (2002) they wrote that the sound level category of 66 – 70 dB(A) is to be regarded as the threshold of health impairments. Tables 7 and 8 also show that Zarqa and Irbid city are exposed to noise levels greater than the range of 66 – 70 dB(A) considered as the threshold of health impairments. As a result, many health problems will be resulting from the exposure to these levels. This result agrees with the previous result of social surveys carried out in Zarqa and Irbid. 88.8% of the respondents to the Zarqa survey and 93.14% of they respondents to the Irbid survey said that noise can result in health impacts. Additionally, in a paper by Davis and Masten (2004), they reported that the bed room noise level is 25 – 30 dB(A), all the measured noise levels are very much higher than this level for bed rooms even during the night time, resulting in more possible sleep disturbances due to the noise from the different selected sources in Zarqa and Irbid. This result agrees with the previous result of social surveys carried out in Zarqa and Irbid. 68.8% of the respondents to the Zarqa survey and 72.0% of the respondents to the Irbid survey suffered from sleep disturbances due to noise.

Figures 14 and 15 present the relationships between measured day time and night time statistical noise levels L10, L50, L90 and the equivalent continuous noise level LA_{eq} in the city of Zarqa and Irbid, respectively. The Figures indicate that the statistical noise levels and the equivalent continuous noise level are linearly related according to the following relationship: $L10 = 0.9685\ LA_{eq} + 6.5553$ with a correlation coefficient $R^2 = 097$, $L50 = 0.9567\ LA_{eq} + 0.5781$ with a correlation coefficient $R^2 = 0.91$ and $L90 = 0.7729\ LA_{eq} + 5.8635$ with a correlation coefficient $R^2 = 0.69$ in Zarqa. While in Irbid city $L10 = 0.9715\ LA_{eq} + 6.3596$ with a correlation coefficient $R^2 = 0.97$, $L50 = 0.9781\ LA_{eq} – 0.7465$ with a correlation coefficient $R^2 = 0.92$ and $L90 = 0.8338\ LA_{eq} + 0.9664$ with a correlation coefficient $R^2 = 0.78$. These results suggest that reliable prediction of L10, L50 and

L90 can be made once LA_{eq} is known.

Figures 14 and 15 illustrate that the correlation between L50, L90 and LA_{eq} is worse than that found between L10 and LA_{eq}. Additionally, the figures indicate that data referring to Zarqa city exhibit more data scattering than that referring to Irbid, which reflects at some levels a high randomness of noise level, this is more noticed in the relation between L90 and LA_{eq}.

High scatter of noise data at low percentile sound levels reflects the high randomness of noise level fluctuations in the outdoor environment or the scattering of noise climates. In addition, high scatter of noise can be attributed to the sensitivity of LA_{eq} noise levels to other sources of noise and short – duration noisy events (Jamrah et al., 2006; Piccolo et al., 2004). Generally motor vehicles are responsible for the fluctuations.

CONCLUSIONS

This study was carried out in Zarqa and Irbid to assess and evaluate noise levels from different sources in these cities, to understand the physiological and psychological effect of noise on people and to study the extent of annoyance on people. In this study, we conclude that the city of Zarqa and the city of Irbid in Jordan are environmentally noise polluted.

The measured equivalent continuous noise levels LAeq.d and LAeq.n in Zarqa for mosques were 74.8 and 74.3 dB(A), for schools 68.7 and 51.4 dB(A), for celebration halls 56.6 and 77.5 dB(A), for commercial area 72.3 and 62.6 dB(A), for industrial area 83.1 and 73.6 dB(A), for traffic 84.3 and 76.4 dB(A), for construction and building works 86.9 and 47.8 dB(A). While the measured LAeq.d and LAeq.n in Irbid for mosques were 75.7 and 74.2 dB(A), for schools 69.9 and 50.4 dB(A), for celebration halls 56.0 and 77.5 dB(A), for commercial area 70.8 and 62.4 dB(A), for industrial area 80.1 and 72.2 dB(A), for traffic 83.7 and 75.3 dB(A), for construction and building works 85.9 and 46.6 dB(A). The study also concluded that the mean day time statistical noise levels L10, L50 and L90 throughout Zarqa were 81.5, 67.1 and 54.5 dB(A) for mosques, 74.8, 64.2 and 56.8 dB(A) for schools, 58.6, 56.4 and 51.6 dB(A) for celebration halls, 92.2, 86.4 and 77.4 dB(A) for construction and building works, 75.0, 72.7 and 67.7 dB(A) for commercial area, 88.0, 80.3 and 73.0 dB(A) for industrial area and 88.0, 85.5 and 72.6 dB(A) for traffic. The mean night time L10, L50 and L90 were 81.0, 65.1 and 50.0 dB(A) for mosques, 56.3, 50.0 and 44.1 dB(A) for schools, 81.3, 76.0 and 77.5 dB(A) for celebration halls, 53.0, 45.8 and 40.0 dB(A) for construction and building works, 66.6, 63.0 and 56.5 dB(A) for commercial area, 78.4, 71.1 and 60.2 dB(A) for industrial area, 80.0,75.2 and 68.0 dB(A) for traffic. While throughout Irbid the mean day time L10, L50 and L90 were 81.7, 65.1 and 54.0 dB(A) for mosques, 76.0, 66.7 and 56.4 dB(A) for schools, 58.4, 56.8 and 52.8 dB(A) for celebration halls, 91.2, 85.1 and 76.9 dB(A) for construction and building works, 74.4, 70.4 and 65.3 dB(A) for commercial area, 83.9, 80.0 and 70.0 dB(A) for industrial area, and 87.1, 84.4 and 71.5 dB(A) for traffic. The mean night time L10, L50 and L90 were 80.5, 64.8 and 51.2 dB(A) for mosques, 56.2,48.0 and 42.0 dB(A) for schools, 81.3, 76.0 and 77.5 dB(A) for celebration halls, 50.0, 46.9 and 41.3 dB(A) for construction and building works, 66.8, 61.0 and 54.2 dB(A) for commercial area, 76.1, 70.9 and 61.1 dB(A) for industrial area, 80.4,72.2 and 64.7 dB(A) for traffic. The higher night time noise levels indicate that the problem of noise is not only limited to the day time, but continues even in night time in these cities.

The measured noise levels from the different sources mentioned before in Zarqa and Irbid were higher than those set by Jordanian noise standards. These noise levels are similar to those reported for other cities. In addition, these noise levels are higher than those reported for other cities around the world.

The results of this study revealed that the measured noise levels in Zarqa and Irbid are very much higher than the levels reported for bed room noise level (25 – 30 dB(A)) range even during night time, and higher than the threshold level of health impairment (66 – 70 dB(A)) range, resulting in sleep disturbances and more hazardous health due to noise. The same results were obtained by

the survey that the exposure to high noise levels will affect people in terms of annoyance, loss of concentration, cause hearing related problems and affect the ability of working.

The extent of annoyance depends mainly on the individuals and the listeners attributed to the sound influences annoyance; so that, if listeners dislike the noise content, they are annoyed, and what is considered noise by one listener may be considered desirable by another. If the listeners feel that they can control the noise source, the less likely the noise will be annoying.

Data showed that there is a significant correlation between the measured statistical noise levels and LA_{eq}. This correlation differs from Zarqa to Irbid, that can be explained by the differences in the nature of traffic in both cities.

There are many different ways of reducing the problem of noise and for mitigating the adverse effects. But this will occur after spreading the awareness among people of the noise problems and of the need to find solutions for them, in addition to increased understanding of the nature of sound and its interaction with our environment.

1- Reduction of noise individually by replacing single windows and doors with double windows and doors.
2- Locating the residential buildings far from noise sources.
3- Absorbing materials in front of buildings such as barriers and trees can reduce noise.
4- Reducing the traffic noise at the source, through design of silent engines in trucks and cars, limitation of vehicle speeds, ban on honking of horns in certain areas, reduction of traffic density in residential areas.
5- Making a change in design and operation of machines.
6- Setting a limit, by legislation, to the amount of noise that will be tolerated and improving the situation to be more effective.

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