



ISSN: 0067-2904

## A Study of Some of the Indicators of Noise Pollution in Certain Residential Districts in Fallujah City

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Received: 27/10/2020

Accepted: 21/5/2021

### Abstract

The aim of this study was to evaluate the effects of noise exposure in certain residential districts in Fallujah city. Twenty-nine stations were selected and divided into two groups; the first group was located 50 to 100 metres from the main streets (quiet areas), whilst the second was located directly on the main streets. Noise levels were measured at a rate of three readings per station for different time periods for approximately sixty days in the year 2020. Mean values were taken in both the morning and evening using a portable sound level meter (Auto range, RS-232). The highest noise level was measured at Alforkan station for the morning reading (83.8 dB) within the second group, while the lowest noise level was measured at Alshohada alawla district station for the morning reading (63.2 dB) within the first group. As for the results of the daily noise level in the evening, the highest daily average (79.4 dB) was measured at Jaish al Shabi street, while the lowest daily average (56.4 dB) was at Dor Alsekak district. The total average noise levels for the morning measurements for the first and second groups were 66.7 dB and 77.2 dB, respectively, whereas those for evening measurements were 65.3 dB and 71.7 dB, respectively. According to field measurements, the average values for the noise (traffic) for the first and second groups in the morning and afternoon exceeded 68 dB, which may cause people to feel very disturbed according to the WHO guidelines on exposure to external environmental noise. In general, all the results measured in this study are above the limits allowed both locally and internationally. This is due to certain erroneous practices in daily activities in addition to the irregular spread of electric generators and commercial activities as well as heavy traffic in the city.

**Keywords:** Fallujah city; Noise pollution map; Noise levels meter; Exposure, Environmental noise.

### دراسة لبعض مؤشرات التلوث الضوضائي في أحياء سكنية معينة بمدينة الفلوجة

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### الخلاصة

في هذا العمل تم قياس بعض مؤشرات التلوث الضوضائي في أحياء سكنية معينة في مدينة الفلوجة. تم قياس 29 محطة تم تقسيمها إلى مجموعتين المجموعة الأولى تقع على بعد 50 إلى 100 متر من الشوارع الرئيسية (المناطق الهادئة) ، والثانية تقع مباشرة على الشوارع الرئيسية. تم قياس مستويات الضوضاء بمعدل ثلاث قراءات لكل محطة في كل من الصباح والمساء باستخدام مقياس مستوى الصوت المحمول (النطاق التلقائي، RS-232). تم قياس أعلى مستوى ضوضاء في محطة (Alforkan) حيث كانت القراءة الصباحية (83.8 ديسيبل) ضمن المجموعة الثانية، بينما تم قياس أقل مستوى ضوضاء في محطة (Alshohada) (63.2 ديسيبل) ضمن المجموعة الأولى. أما بالنسبة لنتائج مستوى الضجيج اليومي في المساء ، فقد تم قياس أعلى معدل يومي (79.4 ديسيبل) في شارع الجيش الشعبي ، بينما كان أدنى معدل يومي في المساء (56.4 ديسيبل) في محطة دور السكك (Dor alsekak). كان متوسط مستوى الضوضاء الإجمالي للقياسات الصباحية للمجموعتين الأولى والثانية (66.7 ديسيبل) و (77.2 ديسيبل) على التوالي ، وبالنسبة للقياسات المسائية ، كان متوسط مستوى الضوضاء الإجمالي لكل من المجموعتين الأولى والثانية (65.3 ديسيبل) و (71.7 ديسيبل) على التوالي. وفقاً للقياسات الميدانية ، تجاوز متوسط قيم الضوضاء (حركة المرور) للمجموعتين الأولى والثانية في الصباح وبعد الظهر 68 ديسيبل، مما قد يتسبب في شعور الناس بالانزعاج الشديد وفقاً لإرشادات منظمة الصحة العالمية بشأن التعرض للضوضاء البيئية الخارجية. بشكل عام ، جميع النتائج التي تم قياسها في هذه الدراسة أعلى من الحدود المسموح بها على الصعيدين المحلي والدولي. ويرجع ذلك إلى بعض الممارسات الخاطئة في الأنشطة اليومية بالإضافة إلى الانتشار غير المنتظم للمولدات الكهربائية والأنشطة التجارية بالإضافة إلى الازدحام المروري في المدينة.

### 1. Introduction

The term 'noise pollution' was coined to signify the vast cacophony of sounds that are produced as a consequence of modern life, leading to certain associated health hazards [1]. The term noise is commonly used to describe 'unwanted sound', or sounds that are unpleasant or disagreeable and produced by acoustic waves of random intensities and frequencies [2, 3]. When people are exposed to excessive amounts of sound waves, their health can be put at risk [4]. As one of the most common environmental problems, noise pollution in modern cities has been causing many short-term and long-term health problems [5]. In the last three decades, with the identification of the dangers noise pollution poses to human health, this type of pollution has become of increasing interest to researchers [6]. Road traffic noise is a growing challenge for human health in the last decades. The World Health Organization (WHO) summarized the scientific evidence on side effects of noise on public health and wellbeing since 1999 in its publication "Guidelines for community noise" [7]. Various studies have shown that short and long-term exposure to noise can not only reduce human hearing, but also increase blood pressure and increase the risk of cardiovascular disease, anxiety, and insomnia [8]. Exposure to noise may lead to various physiological and psychological effects [9] can increase the rate at which one has to visit physicians, and increases drug use in the community [10]. It has been reported that the noise caused by urban traffic can lead to an increase in ischemic heart disease [11, 12]. Further, another study reported that increasing noise pollution could increase pain amongst patients who are hospitalized [13].

Various types of disorders, injury, disturbance, and annoyance may result from the effects of noise. These effects may be physiological, pathological, or mental; a distinction is made between the effects on organs of perception, such as hearing and others, and the more general effects. Auditory stress occurs only if the sound or noise level is sufficiently intense (at least 60 or 70 dB); below this level, exposure may continue for a very long time without ever causing auditory fatigue [14]. According to the "Environmental Legislation Guides in Kurdistan Region – Iraq (ELGKI)", sounds with intensity exceeding 60 dB are considered to be noises, whilst those with intensity exceeding 65 dB are considered noises that have a negative impact on quality of life. Sounds exceeding 70 dB are considered harmful to human health, and it is advisable not to be exposed to such noises [15]. According to the "Occupational Safety and Health Administration (OSHA)" in the U.S.A, exposure for more than 8 hours a day to sound over 85 dB is highly risky and is used as a warning limit, whilst

the sound levels of 90 dB or greater are considered dangerous on exposure for more than eight hours per day [2,14]. Nowadays, noise pollution is the third-most hazardous environmental type of pollution according to the "World Health Organization (WHO)" and is preceded only by air and water pollution [16, 17, 18]. The acceptable equivalent sound levels at outdoor living area for 16 h/day and their associated effects on human health are > 50 moderate annoyances and > 55 serious annoyances [17, 19].

In countries with severe social problems such as Iraq, urban noise is quite uncommon on the list of priorities, and thus has received very little attention. Nowadays, many pollutants are released into the environment with their associated risks to human health. Noise pollution is one of the various anthropogenic pollutants. Movement of hundreds of thousands of cars, industrial activities, and constructions in large cities are the main sources of noise pollution [20]. The Fallujah grew from a small city in 1947 to a city with a population of 275,128 inhabitants in 2011 [21]. Increasing number of vehicles in Fallujah city has led to the appearance of noise pollution. To the best of our knowledge, no studies published to date have reported noise pollution in Fallujah city, Iraq.

The aim of the study is to measure noise pollution resulting from loud sounds in certain neighborhoods of the city of Fallujah and compare the results with the standard international noise pollution limits.

## 2. Theory

A sound is a wave that vibrates the molecules of some medium and moves from one place to another via that medium (air, water, etc.) in the form of compressions and rarefaction. For this reason, the sound is a pressure wave and it is one of the types of physical energy circulating as waves. It is also a vibrational energy. One of the most important measures of sound is sound pressure, generated by a non-atmospheric sound wave in bounded space. Sound pressure is the change in air pressure during the vibration over a period of time. Baseline audio compression is accepted to  $2 \times 10^{-5}$  Pa at the hearing limit of 1000 Hz [22]. Although changes in sound pressure can be measured accurately, it is very difficult to use a microphone to measure the speed of sound. Sound measurements are made at an appropriate distance (approx. 1 meter) from the source to maintain the audio compression ratio and the speed of sound. The level of sound intensity ( $L_I$ ) is the logarithm of the ratio of a physical magnitude to a given basic value, as shown in equation 2. The meaning of dB is the perceived volume or noise level unit [22].

The basic sound level  $I_0$  for the volume level, with a hearing limit at 1000 Hz, is:

$$L_I = 10 \cdot \text{Log} \frac{I}{I_0} [\text{db}] \quad (1)$$

The intensity  $L_p$  is proportional to the square of the sound pressure ( $I \sim p^2$ ). On this basis, the volumetric pressure level becomes [22]:

$$L_p = 10 \cdot \log \frac{p^2}{p_0^2} = 20 \cdot \log \frac{p}{p_0} \quad (2)$$

The basic sound pressure ( $p_0$ ) here is the sound pressure at the hearing limit of 1kHz, which is accepted as  $2 \times 10^{-5}$  Pa. The number of wave peaks observed in one second is called frequency and the distance between two peaks is called the wavelength. The audio frequency indicates the number of vibrations of the sound per second. Voice waves have the shape of a sine wave. In other words, the amount of pressure varies per unit time [22].

## 3. Materials and methods

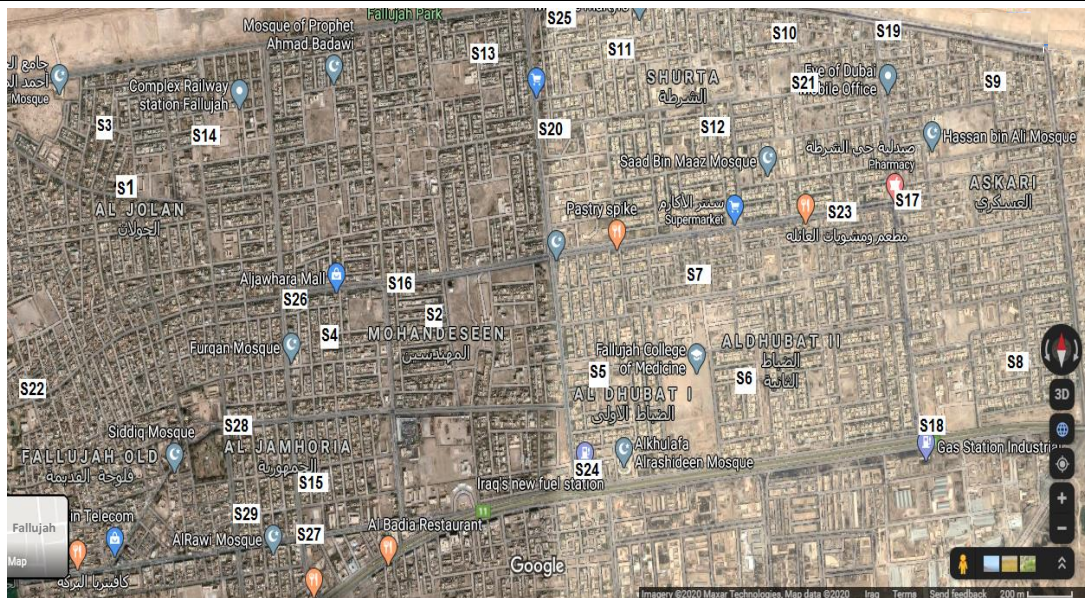
Measurements were performed in the city of Fallujah, located within the administrative boundaries of Anbar Province in the west of Iraq. The city is located 69 km west of the capital, Baghdad. In the current study, 29 stations (S1, S2, ..., S29) were selected to measure the noise level in different regions of the city, as shown in Table 1 and Figure-1. The stations were divided into two groups, the first group being located 50 to 100 metres from the main streets (quiet areas), and the second is located on the main streets themselves. The noise level was measured at a rate of three readings per station in the morning and three in the evening using a portable sound level meter (Auto range, RS-232) [23,24]. Sound level (SL) meter has been designed to approximate the loudness level sensitivity of the human ear. It gives reproducible measurements for the sound pressure level. The SL meter used in this study was of the model Auto range, RS-232. This sound level detector is a digital meter for measuring the SL in decibels (dB). Its accuracy =  $\pm 1.5$  (dB) (Figure-2).

**3.1. Statistical analysis**

The data were analyzed using a two-way ANOVA following general linear model (GLM) procedure at  $p < 0.05$  to identify the significant differences in selected parameters among distance and time. Significant differences between means were tested using Tukey's HSD (Honestly Significant Difference) method. All statistical analyses were performed using the Minitab software package 17.

**Table 1-** Names of stations at which measurements were taken in the city of Falluja

Station no.	Station name	Station no.	Station name
S1	Aljulan district.	S16	Crossroads Fortieth St. with Nationality St.
S2	Almuhandesen district.	S17	crossroads Fortieth St. with Jaish al shabi St.
S3	Alshohada alawla district.	S18	Jaish al shabi St. district 1
S4	Alwahda district.	S19	Jaish al shabi St. district 2
S5	Aldhobad alawla district.	S20	Alshareka St. district 1
S6	Aldhobad althania district	S21	Alshareka St. district 2
S7	Dor alsement district	S22	Fortieth St. district 1
S8	Alaskari district. 1	S23	Fortieth St. district 2
S9	Alaskari district. 2	S24	Altherthar St. district 1
S10	Aljogaifi district. east	S25	Altherthar St. district 2
S11	Aljogaifi district. West	S26	Alforkan St. district 1
S12	Alshorta district.	S27	Alforkan St. district 2
S13	Almualemen district.	S28	Public park St. district 1
S14	Dor alsekak district.	S29	Public park St. district 2
S15	Aljemhorea district.		



**Figure 1-** Map of Falluja showing the stations of the present study of noise measuring.



**Figure 2-** Auto range RS-232 sound measuring device used in the present study.

#### 4. Results and discussion

Depending on the results obtained from the analysis of variance, there was a significant difference ( $F_{1, 52} = 56.32$ ;  $P = 0.000$ ) in the mean noise value based on distance (first group and second group) (Tables- 2 and 3). Higher level of noise was recorded in the second group with a mean value of 74.51dB as compared to the first group (66.04 dB). Regarding the effect of time (morning and evening), it was observed that noise was significantly different ( $P=0.005$ ) with time. Morning showed significantly greater level of noise (71.96 dB) as compared to evening (68.58dB).

Concerning the interaction effect between distance and time, it was observed that the interaction was not significant, which indicates that the sound level changed with time in the same manner in both distances (Tables- 2-3).

**Table 2-** Analysis of variance of distance (first group and second group), time (morning and evening) and interaction between them on noise level in the city of Fallujah

Variables	Distance		Time		Distance × Time	
	$F_{1,52}$	$P$	$F_{1,52}$	$P$	$F_{1,52}$	$P$
Noise level (dB)	56.32	0.000	8.80	0.005	3.37	0.072

**Table 3-** Effects of distance (first group and second group), time (morning and evening), and their interaction on noise level (dB) in the city of Fallujah

Distance	Time		Main effect
	Morning	Evening	
first group	66.70c	65.38c	66.04 A
second group	77.22a	71.79b	74.51B
Main effect	71.96A	68.58B	

Means that do not share a letter are significantly different at  $p < 0.05$ .

Table-4 indicates the average of the morning measurements for all stations, where the highest value of noise level (83.83 dB) was at station S26 (Alforkan Street district 1), while the lowest value (63.27 dB) was at station S3 (Alshohada alawla district). Auditory fatigue occurs only if the sound or noise level is sufficiently intense, at least from 60 dB to 70 dB. Accordingly, the results of noise levels obtained in the present study are high and imply that the recorded noise values can lead to auditory fatigue. According to the measurements made during the morning in the first group, the average sound level was determined to be between 63.27-73.53 dB, where the lowest and highest sound levels were recorded at stations S3 and S10, respectively (Table- 4). The high values recorded in these stations are due to their vicinity to electric generators. Also, high average sound levels were recorded in stations S8, S11, and S12 (68.67, 70.27, and 69.5 dB, respectively), due to electric generators being near to these stations. Based on WHO guidelines [19, 24-26], average noise levels of 50 dB can induce moderate annoyance, and those of 55 dB can induce serious annoyance [27, 28]. All the sound levels in the current study are above 60 dB (Table- 4), and the monitored average sound level for all stations was 66.70 dB, which suggests that noise pollution is serious in Fallujah. According to the measurements made during the morning in the second group, the average sound level was determined to be between 70.5-83.83 dB, where the lowest and highest sound levels being recorded in stations S20 and S26, respectively, as shown in Table-4. Also, a high average sound level was recorded in stations S18, S22, S23, S24, S25 and S27. According to the guidelines of the ELGKI, sounds exceeding 70 dB are considered harmful to human health, and it is advised not to be exposed to such noises [15]. All of the traffic sound levels recorded in the present investigation are above 70.5 dB (Table-4), and the monitored sound level average for all the roads was 77.22 dB, which suggests that the traffic noise pollution is serious in Fallujah.

**Table 4-** Noise pollution measurements for the study stations in the city of Fallujah in the morning time (dB).

Station no.	Mean value of Noise (dB) in the	Station no.	Mean value of Noise (dB)
S1	64.73	S16	75.06
S2	66.86	S17	71.83
S3	63.27	S18	78.26
S4	63.93	S19	73.6
S5	67.26	S20	70.5
S6	63.86	S21	74
S7	63.9	S22	79.8
S8	68.66	S23	79.9
S9	66.56	S24	81.96
S10	73.53	S25	78.06
S11	70.26	S26	83.83
S12	69.5	S27	81.36
S13	65.7	S28	76.5
S14	65.1	S29	76.4
S15	67.33		

Table-5 indicates the average for the evening measurements for all stations, where the highest noise pollution (79.47 dB) was at station S18 (Jaish al shabi Street district 1). This indicates the presence of noise pollution that is both high and harmful to human health [15]. The lowest noise pollution measurement rate (56.47 dB) was at station S14 (Dor alsekak district), where this level might induce serious annoyance upon exposure for a long time. The full set of measurements is tabulated in Table-5. According to the measurements taken during the evening for the first group, the average sound level was determined to lie between 56.47-70.9 dB, while the lowest and highest sound levels were at stations S14 and S5, respectively, as shown in Table-5. Also, the highest average sound level was recorded at stations S2, S4 and S7. The high magnitudes recorded at these stations were because they are close to electric generators. Most of the sound levels were above 60 dB (Table-5) and the average monitored sound level for all stations was 65.3 dB, which again suggests that noise pollution is serious in Fallujah. According to the measurements taken during the evening in the second group, the average sound level was between 62.9-79.47 dB, with the lowest and highest sound levels being at stations S29 and S18, respectively, as shown in Table-5. Also, the highest average sound level was recorded at station S23. Most of the traffic sound levels are above 70 dB (Table-5) and the monitored sound level for all the roads on average was 71.79 dB, which again suggests that the traffic noise pollution is serious in Fallujah.

**Table 5-** Noise pollution measurements for the study stations in the city of Fallujah in the evening time (dB).

Station no.	Mean value of Noise (dB) in the Evening (8:10 PM)	Station no.	Mean value of Noise (dB) in the Evening (8:10 PM)
S1	64.3	S16	77.33
S2	69.36	S17	74.9
S3	63.13	S18	79.46
S4	69.03	S19	69.8
S5	70.9	S20	72.13
S6	65.7	S21	67.13
S7	69.16	S22	74.03
S8	68.6	S23	78.83
S9	70.36	S24	70.56
S10	64.1	S25	74.56



S11	59.8	S26	71.26
S12	58.2	S27	66.83
S13	66.13	S28	65.3
S14	56.46	S29	62.9
S15	64.23		

Table-6 and Figure-3 compare between morning and evening measurements of noise pollution in the city of Fallujah for all stations.

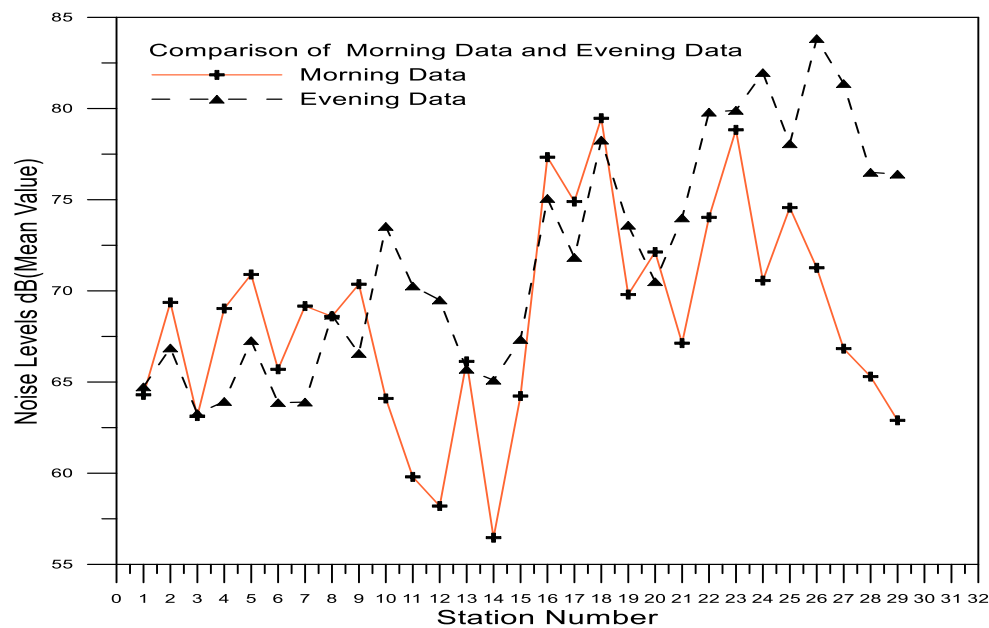
Table-6 illustrates the means of noise levels and standard deviation at all studied stations during both morning and evening times. Depending on the measurement of noise rerecorded in the morning, it can be observed that the level of noise was significantly higher ( $p < 0.001$ ) at stations S10, S11, and S16-S29 in comparison to other stations. The highest levels of noise were found to be between 70.27 – 83.83 dB, while the lowest were between 63.27 – 68.67dB.

According to the noise measurement made in the evening, significantly higher levels of noise ( $p < 0.001$ ) were recorded at station S16 – S27, S2, S4, S5, and S7-S9, while lower values of noise were detected at the other stations. The highest values of noise ranged 66.83 -79.47dB and the lowest values ranged 56.47 – 66.13dB.

**Table 6-** Noise levels under different locations during morning and evening times.

Location	Noise (dB) morning		Noise (dB) evening	
	Mean	Standard deviation	Mean	Standard deviation
S1	64.73jk	8.88	64.30g-m	1.87
S2	66.87hijk	5.57	69.37d-j	3.01
S3	63.27k	5.41	63.13i-m	1.72
S4	63.93jk	5.36	69.03d-j	7.15
S5	67.27g-k	4.22	70.90c-i	5.41
S6	63.87jk	10.33	65.70g-l	3.17
S7	63.90jk	3.64	69.17d-j	6.03
S8	68.67f-k	5.23	68.60d-j	6.36
S9	66.57hijk	5.98	70.37c-j	7.16
S10	73.53c-i	0.61	64.10h-m	5.63
S11	70.27e-k	1.01	59.80klm	4.44
S12	69.50f-k	6.98	58.20lm	7.71
S13	65.70ijk	8.47	66.13f-k	4.28
S14	65.10jk	1.55	56.47m	3.90
S15	67.33g-k	6.62	64.23g-m	2.08
S16	75.07b-g	2.01	77.33abc	1.16
S17	71.83d-j	3.00	74.90a-c	2.82
S18	78.27a-e	5.80	79.47a	1.41
S19	73.60c-i	1.91	69.80c-j	1.57
S20	70.50e-k	0.66	72.13a-g	7.86
S21	74.00b-h	0.95	67.13d-k	1.97
S22	79.80abcd	3.03	74.03a-f	8.91
S23	79.90abc	3.44	78.83ab	6.16
S24	81.97ab	3.31	70.57c-j	1.17
S25	78.07a-e	2.78	74.57a-e	4.52
S26	83.83a	1.21	71.27b-h	5.42
S27	81.37abc	6.10	66.83e-k	4.92
S28	76.50a-f	0.66	65.30g-l	2.96

S29	76.40a-f	5.92	62.90jklm	3.95
P – value	<0.001		< 0.001	
Means in each column having the same litter are not significantly different at p-value = 0.05.				



**Figure 3-** A comparison between morning and evening measurements of noise pollution in the city of Fallujah.

## 5. Conclusions

In this study, noise levels were measured at 29 stations (S1, S2, ..., S29) in different regions of the city of Fallujah, where the stations were divided into two groups. Noise levels were measured using a portable sound level meter (Auto range, RS-232) by a mean value of three readings per station in the morning and three in the evening for sixty days. In the morning time measurement for all stations, the highest noise pollution was at station S26 (Alforkan Street district 1) and the monitored sound level for all stations was 71.78 dB on average. The results of this study indicate that the peak levels, i.e., 83.83 dB, of traffic noise were very serious in Fallujah.

The results of the evening measurements for all stations indicated that the highest noise pollution recorded was at station S18 (Jaish al shabi Street district 1) and the average for all stations was 68.43 dB.

The results obtained from analysis of variance clarify that there was a significant difference ( $F_{1,52} = 56.32$ ;  $P = 0.000$ ) in noise mean based on distance (first group and second groups). Regarding the effect of time (morning and evening), it was observed that noise was significantly different ( $p=0.005$ ) with time.

According to field measurements, the average values for the first and second groups' (traffic) noise in the mornings and afternoons exceeded 68 dB, which could make people feel quite disturbed according to the WHO outdoor environmental noise exposure guidelines.

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