
Assessment of Traffic Noise Pollution in Al-Khobar, a Typical City in the Kingdom of Saudi Arabia

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Abstract :

The paper reports on a survey of the traffic noise pollution in al-Khobar city. The main objective of this study was to evaluate traffic noise pollution in the kingdom of Saudi Arabia (KSA) cities. Four major streets were monitored: those are, Dhahran, king abdulaziz, Amir Turki street and twenty eight. The monitoring was conducted for a duration of 24 hours for most of the selected locations. Equivalent A-weighted sound pressure level (L_{Aeq}) index was used, and the effect of workday and weekend traffic were investigated. A variation noticed in the results.

The results indicate that traffic noise levels in al-Khobar are higher than those recommended by noise standards for the day, afternoon and evening periods residential and commercial areas. Spectral analyses of the sound pressure show consistent behavior of typical spectrum of freely flowing traffic stream. The study confirms the urgent need to establish a center in the Kingdom of Saudi Arabia for noise pollution monitoring and to develop local traffic noise standards.

Key word:

noise pollution assessment, traffic noise, KSA noise survey.

1. Introduction :

Environmental pollution is a major issue of concern for most modern cities nowadays. Noise is one of the major contributors to environmental pollution with road traffic most widespread source of noise and primary cause of annoyance and interference in all countries. Noise reduction, thus, attained urgent resolution priority in affected developed countries, where noises surveys were conducted and peoples responses extensively investigated, for the purpose of establishing bylaws and regulations for noise control [1, 2].

The Kingdom of Saudi Arabia (KSA) experienced fast development, with rapid growth of cities and extensive urban extensions and high population growth. This evidently accelerated the demands for increased transportation facilities, i.e. cars, bus, trains, airplanes etc... and with subsequent increased impact of noise pollutions in main local urban centers.

The seriousness of the traffic noise as the major source of environmental pollution was clearly exposed by a number of previous studies [1]. Survey studies conducted in Germany and Vienna showed that road traffic noise effects were particularly acute in urban areas and contributed significantly to the overall noise pollution [2, 3]. Similarly, the seriousness and excessive impact of urban noise on the population was explored by previous survey studies. These generally confirmed that the major portions of population were commonly exposed to an A-weighted noise levels exceeding 65 dB [4-6]. Due to these numbers, it is evident that the control of the noise emission from road vehicles is of paramount importance for the reduction of environmental noise.

Noise measurements commonly conducted at various cities used measurement indicators represented by the mean values of the statistical noise levels L90, L50, L10, i.e. representing noise levels exceeding 90 per cent, 50 per cent and 10 per cent of the measuring time, consecutively. These measurements of environmental noise pollution showed closeness of data obtained and evaluated for the different indicators. The results also confirmed the greater impact due to road traffic noise during day time which generally exceeded environmental standards by more than 10 dBA [7]. The excessiveness of noise levels from set noise standards were also established by studies at different urban centers and cities [8]. Very higher noise levels were recorded in excess of LAeq=80 dB in residential areas. Such high noise levels were shown by social surveys carried out simultaneously to cause sever and serious irritation, as expressed by majority of population of 73.8% [9].

Traffic noise problem were also explored in Saudi cities of Jeddah and Riyadh. These similarly confirmed that the intensity of noise levels exceeded set standards and limits of dissatisfaction [10, 11]. This raised the need to address noise pollution problems and particularly traffic noise in major local urban cities. It is essential to investigate the extent of traffic noise problems and to high-light the danger of environmental deteriorations that can be ensued and to explore the effectiveness of corrective and planning measures. This study, thus, explores these issues raised and taking the city of Al-Khobar as one of the major modern Saudi cities as study case.

2. Methodology

2.1 Site selection

Al-Khobar, located in Eastern Province of Saudi Arabia, was selected as typically representative modern city to perform the study on aspect of local noise pollution. Al-Khobar witness extensive urban development over the

past decades to become a node for commercial activity characterized by modern and beautiful building and recreation sites. Al-Khobar is currently serviced by several excellent collector roadways. The city centre is bordered by Dhahran street, King Abdulaziz street, AL Amir Turkey road (old cornice) and 28th street (pepsi road) [12,13].

Traffic noise monitoring in Al-Khobar city was conducted at critical nodes of problem roads. These were identified by careful study of city main roads with high traffic volume and included; Dhahran street, king Abdulaziz street and Amir Turki street and 28 streets. These four main streets were selected for the purpose of the study :

- i) Dhahran street is the major road in Al-Khobar city with a width of 80 meters with five lanes in each direction.
- ii) King Abdulaziz Street is the second major road in Al-Khobar city with a width of 60 meters with four lanes in each direction.
- iii) Amir Turki Street is the third major road in Al-Khobar city with a width of 50 meters with three lanes in one direction and five lanes to the sea side.
- iv) Twenty eighth streets is the forth major road in Al-Khobar city with a width of 30 meters with two lanes in each direction.

A total of four locations were selected for monitoring and are referred to on map provided by figure (1) as :

- Location A, at Dhahran street, opposite to Baglaf multistory building, in front of Habitat shop (*al Manzel commercial*),
- location B, at King Abdulaziz street, opposite to multistory building in front of Antennal shop (*ALARIALAT AL ALAMIUAH*),
- location C, at Amir Turki street, opposite to multistory building, in front of bookstore shop (*Jarir bookstore*), and
- location D, at 28th street, opposite to multistory office building, in front of aluminum shop (*al-w opposite to akeel aluminum showroom*).

The measurements locations were selected to ensure the following main practical criteria:

- Proximity to multistory building; having mixed uses such offices or residential and commercial development,
- adjacency to main road with high traffic flow,
- provision for ensuring security of the measuring equipments; and
- validation of traffic as prime contributing source to measurements.

2.2 Measurement protocol

Noise data's collections were performed over twenty four hour period and at two minutes sampling intervals during working day for all selected location. Amir Turk street was monitored twice, during working day and at weekend. Measurements were anticipated to show typical daytime and nighttime noise levels at main street in Al-Khobar. The noise profile at each location represented the quietest and nosiest periods of the day recorded, as well as the effects of rush hour traffic noise. All measurements were handled in accordance with international standard (ISO 199/1, 2, 3) [14].

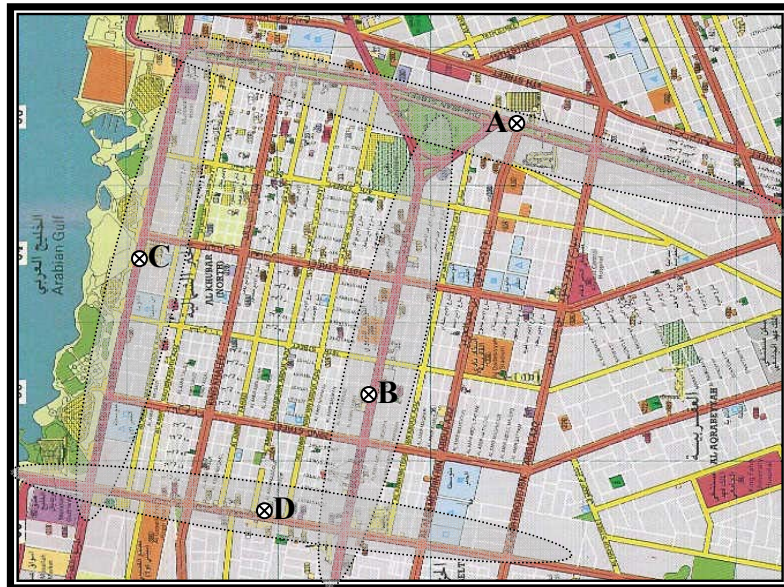


Figure (1) : show roads under investigation and locations positions of traffic noise measurements

2.3 Measurement setup

Traffic noise levels measurements were conducted using investigator type 2260, Outdoor Gear Type 3592 and Outdoor Microphone Kit of B&K products [15]. Outdoor Microphone Kit UA 1404 shields the microphone and preamplifiers against weather and wind noise and ensures proper frequency response and directional response according to IEC and ANSI standards. The measurements were initially stored in the investigator and then transferred to computer in the laboratory using evaluator software type 7820[16]. These instruments used for the conduct of the measurements were provided by the acoustics laboratory of the Building Engineering Department, of the College of Architecture and Planning of King Faisal University. Other needed equipments were purchased through the fund

supporting this project and provided for by the Deanship of Scientific Research.

Measurement of weather parameters were acquired using portable weather station and recorded data for wind speed, direction, temperature and relative humidity. Traffic information density and car numbering count were collected based on direct human counting.

2.4 Measurements indices

The traffic noise statistical descriptors used in this study included the following main descriptors [14, 15]:

- i. Equivalent continuous sound level (L_{Aeq}), which is defined as the steady-state sound that has the same A-weighted level as that of the time-varying sound averaged in energy over the specified time interval.
- ii. X-percentile- exceeded sound level (L_{Ax}). This expresses the fast, A-weighted sound level equaled or exceeded at certain standard set percentages ($x\%$) of the sample time. Most commonly used are L_{10} , L_{50} , and L_{90} , corresponding the levels exceeded 10%, 50%, and 90% of the time, consecutively.

2.5 Traffic noise criteria

An environmental quality criterion for traffic noise is generally required to be maintained in order to protect human's health and preserve the living environment. Saudi standard organization (SASO) was contacted looking for local traffic noise criteria but was not able to provide any reference standard criteria in this regard. It was evident, however, that no local Saudi standards describing road traffic noise criteria were available. Therefore, it was necessary to look at criteria used in other countries in order to consider appropriate guidelines to be used in this research.

Comparison of road traffic noise criteria used for residential areas for different countries, indicate greater variation in noise criteria adopted by different countries [17]. These variations can be attributed to numerous factors, which included; differences in lifestyle, climate conditions and city design. This makes international harmonization of noise limits impossible. Another variant comes from the fact that, noise assessment is carried out using varying reference time duration for measurements, depending on the country. The time duration range from one duration over 24-hours, or two durations (daytime and nighttimes), or three separate durations (day, afternoon and night). Further more, the periods over which the night time L_{Aeq} are calculated also varies considerably from one country to another, and sometimes between regions in one country. This may partly be

explained by the difference in normal sleeping hours in different countries [15, 17].

For the purpose of this research the Egyptian criteria, of three periods durations, was adopted. The adoption of Egyptian criteria can be justified by the similarity of characteristics with Saudi life style. However, further investigation is required to establish suitable local Saudi traffic noise criteria. The Egyptian criteria is regulated by the Ministry of Environment institute, and expressed by the environmental law number 4 of year 1994 and its executive regulation, which determined the maximum permissible limit for noise intensity in different areas as shown in table (1) [18].

Table (1)
Egyptian statutory standards regulations adopted.

TYPE OF AREA	PERMISSIBLE LIMIT FOR NOISE INTENSITY DECIBEL (A)					
	Day time		after time		Night time	
Commercial, administrative and downtown areas	55	65	50	60	45	55
Residential areas in which can be found some workshops or commercial establishments or which are located on a main road	50	60	45	55	40	50
Residential areas in the city	45	55	40	50	35	45
Residential suburbs with low traffic	40	50	35	45	30	40
Residential rural areas, hospitals and gardens	35	45	30	40	25	35
Industrial areas (heavy industries)	60	70	55	65	50	60

2.6 Conditions at measurements locations

Traffic noise measurements were conducted at the four locations of the four main streets in Al-Khobar area, the following conditions were observed during the monitoring periods at the different locations.

- i. Dhahran Street showed traffic volume exceeding 7200 cars per hour sampled at 7:30 am and speed limit at low speed lane of 60 km/h and at high speed lane of 80 km/h. Ambient temperature recorded was 32.4 °C, relative humidity 38%, average wind speed 0.7m/s and maximum of 1.5m/s. The measurements of traffic noise level were recorded over 24 hour on workday (Sunday) starting from 7:56 am.

- ii. King Abdulaziz showed traffic volume exceeding 6600 cars per hour sampled at 7:30 am and speed limit of 60 km/h. Ambient temperature recorded was 35°C, relative humidity 60 %, average wind speed 1.2 m/s and maximum 2 m/s. The measurements of traffic noise level was recorded over 24 on workday (Sunday) starting from 7:25 am.
- iii. Amir Turki street showed traffic volume exceeding 5000 cars per hour sampled at 8:30 am and speed limit of 80 km/h. Ambient temperature recorded was 32.5°C, and relative humidity 61 %, average wind speed 1.0 m/s and maximum of 1.8 m/s. The monitoring was conducted twice for this street, during weekend day and workday. The primary intention was to observe the difference due to traffic noise during working days and weekends. Traffic noise level monitoring during weekend was recorded over 24 hour, starting from 7:40 am. Monitoring on workday was conducted for 11 hours period from 7 am to 6pm.
- iv. The traffic volume at the Twenty eighth streets was shown to exceed 4200 cars per hour sampled at 8:15 am and speed limit of 60 km/h . Ambient temperature recorded was 32.0 ° C, relative humidity 27 %, and average wind speed 1.0 m/s and maximum of 1.7 m/s. Similarly the measurements were recorded over 24 hours duration workday.

3. Results Analyses:

Traffic noise characteristics are explained by three sets of measurements which dealt with the following main aspect:

- i. Traffic noise profile, which was measured by three main descriptors, L_{Aeq} , L_{ASmax} and L_{ASmin} ,
- ii. traffic noise spectral analysis, and
- iii. percentile level of traffic noise.

The traffic noise profile measured at Dhahran street is shown by the diagram of figure (2a) and represented by three curves for equivalent sound pressure level in dBA, minimum level and the maximum level. The traffic noise profile over the 24 hour monitoring period for L_{Aeq} and L_{ASmax} and L_{ASmin} , generally showed consistent trend for levels exceeding 70 dBA, except from 1:20 am to 5:26 am which indicated lower noise levels below 70 dBA. Minimum traffic noise level recorded at 3:52 am of 62.3 dBA and maximum of 75 dBA at 4:28 pm.

Comparison of monitored traffic noise levels shown in the figure with adopted noise standards of table (1), for the commercial/Residential area clearly indicate that, the L_{Aeq} generally exceeds the maximum limit of 60

dBa set by the standard by about 11 dB, at day time. Similarly the maximum limit of 55 dBA set by the standard is exceeded by about 17 dB at the evening. Also the maximum limit of 50 dBA set by the standard is exceeded by 12 dB for night time at 3:52 am. This indicates serious traffic noise level problem at all times at this street. Urgent resolution is evidently required, particularly with realistic expectation of increased high traffic volume in near future consistent with increasing rate of population growth in the kingdom.

Converting spectral analysis for the average level shown by figure (2b) into dB, illustrates the behavior of typical spectrum for freely flowing traffic streams characteristics. This shows a maximum level at frequency of 63 Hz, which represents the firing frequency for the majority of vehicles at cruising speed. High level around frequency 1 kHz is recognized to be due to tire and wind noise.

Figure 2c shows the percentile levels. The L10 which represents the peak level and is shown to be about 76.3 dB. The L90 which represents the traffic noise background level is measured as 57.7 dB. The L50 level is measured at about 68.2 dBA. Comparing these readings evidently indicates that they exceed other international and Japanese standards for daytime limit of 60 dBA.

Traffic noise profile measurements for king Abdulaziz Street also show similar profile to that of Dhahran street shown by figure 3a. Traffic noise show a constant trend of LAeq level exceeding 70 dBA over the monitoring period but with lower levels below 70 dBA from 10:35 am to 5:51 am. Minimum traffic noise level recorded at 2:37 am of 50.4 dBA and maximum of 75.6 dBA recorded at 6:39 am. Comparing the recorded levels with standards for similar land use show that, at day time the LAeq level exceeds the maximum limit by more than 11 dB. Similarly, at the evening the maximum limit is exceeded by 15 dB and at night time by more than 10 dB. The spectral analysis of the average level shown by figure 3b, also shows similar behavior as noticed on Dhahran street. Figure 3c shows the percentile levels The L10 is 76.5 dB and the L90 is 62.6 dB and the L50 is 69.4 dB.

Traffic noise profile measurements for Amir Turki Street shown in Figure 4a, also show similar profile. The measurements obtained indicate fluctuation of traffic noise level for most of the time, although exceeding the 70 dBA level during all of the monitoring period. The LAeq level is more than 75 dBA from 8:15 am to 8:10 pm and from 12am mid night to 3:30 am.

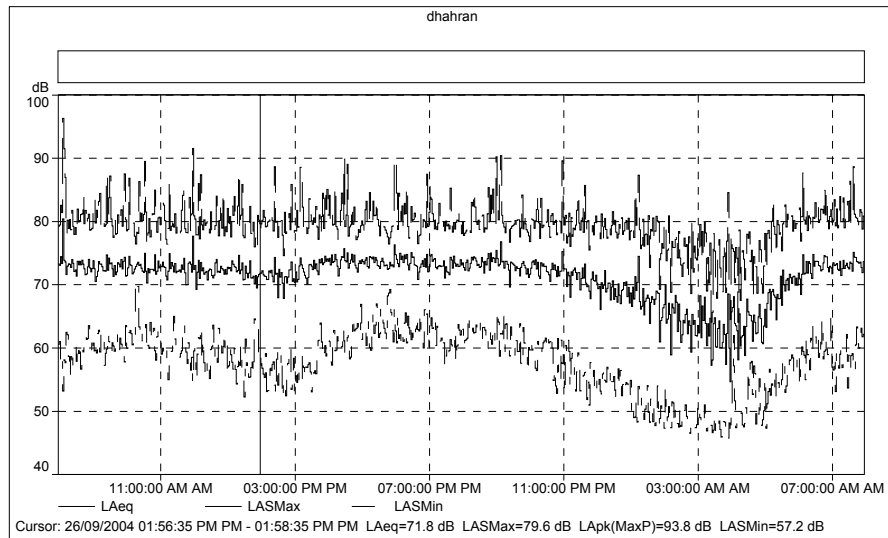


Figure (2a) : Typical traffic noise profile, illustrated for Dhahran Street measured on workday.

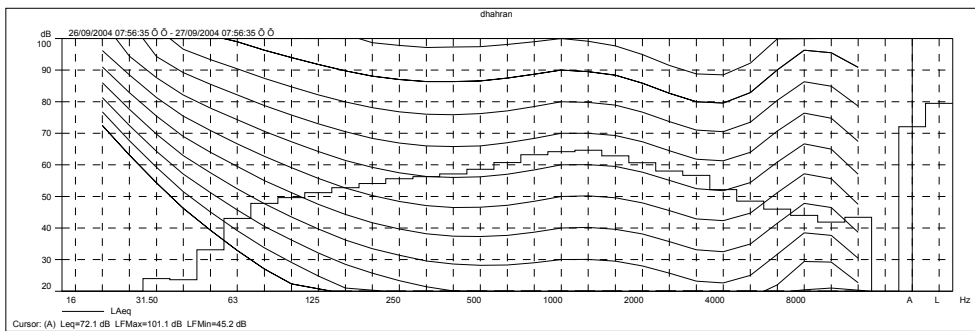


Figure (2b) : Typical spectral analysis traffic noise, illustrated for Dhahran Street measured on workday.

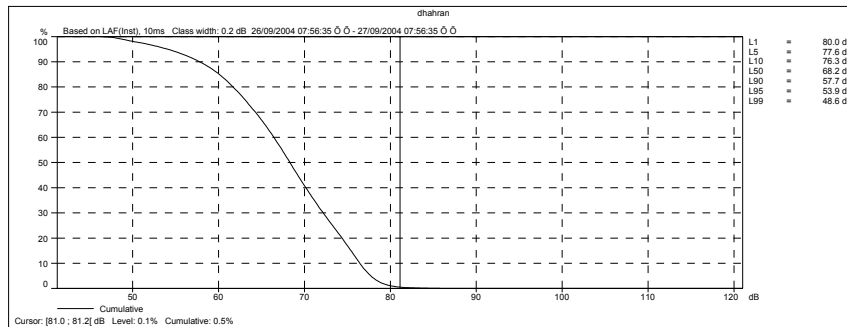


Figure (2c): Typical percentile level of traffic noise, illustrated for Dhahran Street measured on workday

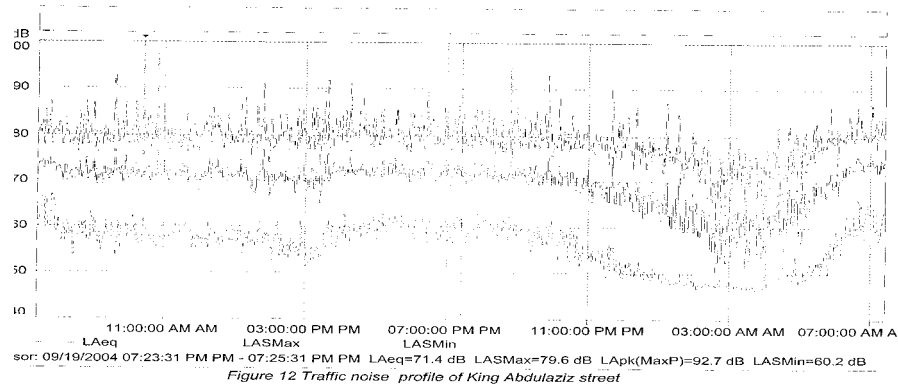


Figure (3a) : Typical traffic noise profile, illustrated for King Abdulaziz Street measured on workday.

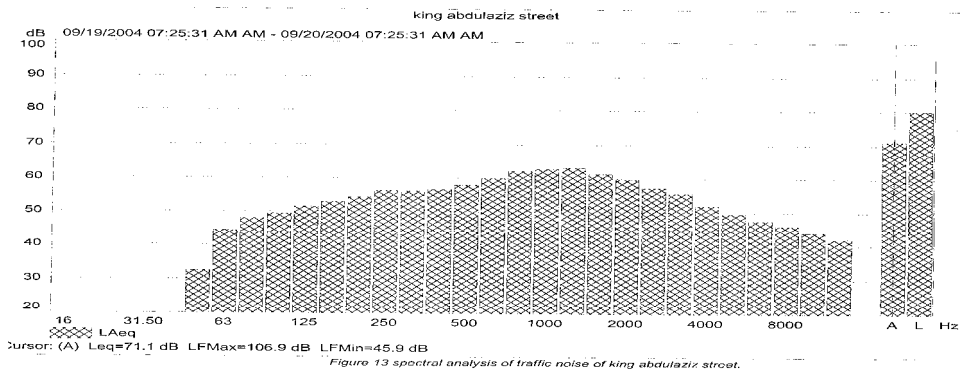


Figure (3b) : Typical spectral analysis traffic noise, illustrated for King Abdulaziz Street measured on workday.

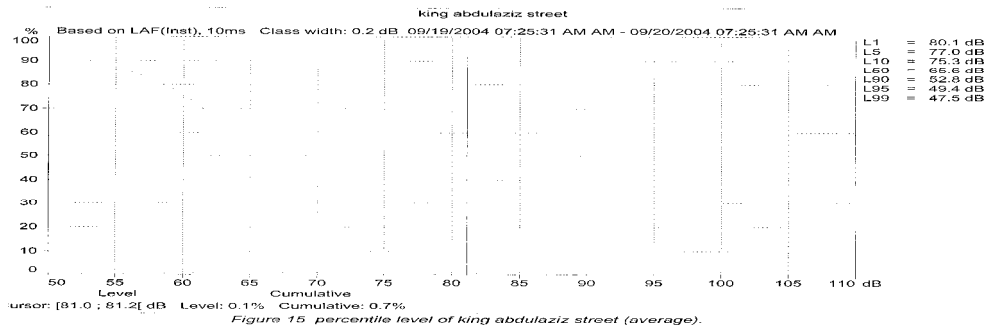


Figure (3c): Typical percentile level of traffic noise, illustrated for King Abdulaziz Street measured on workday.

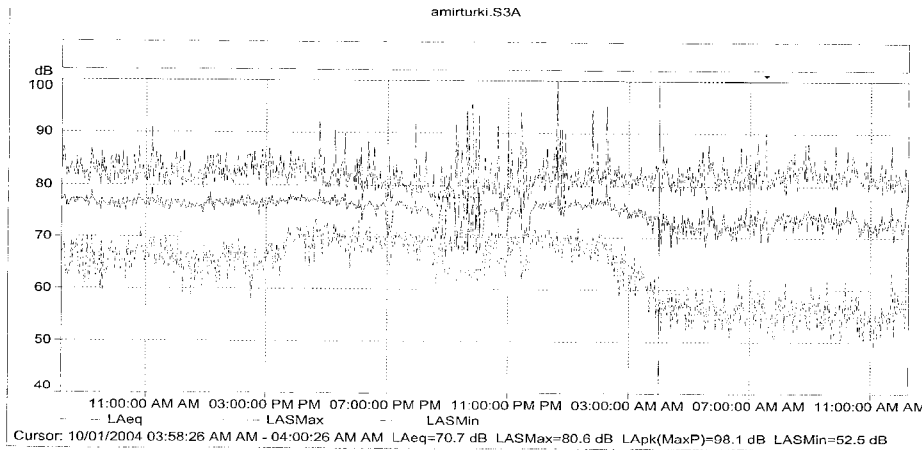


Figure 22 Traffic noise profile of Amir Turki (Cornish) measured on weekend day for 28 hour.

Figure (4a) : Typical traffic noise profile, illustrated for Amir Turki Street measured on weekend.

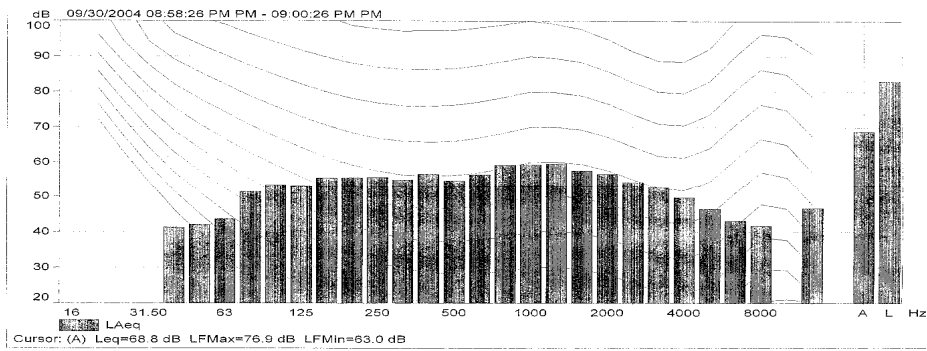


Figure 23 Spectral analysis of traffic noise of Amir Turki(Cornish) for 28 hour weekend.

Figure (4b) : Typical spectral analysis traffic noise, illustrated for Amir Turki Street measured on weekend.

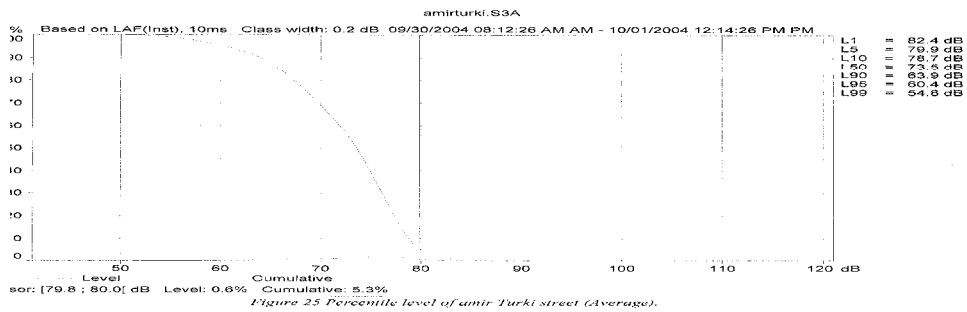


Figure 25 Percentile level of Amir Turki street (Average).

Figure (4c) : Typical percentile level of traffic noise, illustrated for for Amir Turki Street measured on weekend.

However, the L_{Aeq} also drops to 70 dBA from 8:10 pm to 9:38 pm and with a minimum traffic noise level of 68.8 dBA at 9:00 pm and maximum of 78 dBA at 3:48 pm. Comparisons of the recorded traffic noise with standards for similar land use shows that, the L_{Aeq} exceeds the standard by 15 dB at day time, by more than 13 dB at the evening and by more than 20 dB at night time. Spectral analysis (Figure 4b) for the average level also indicates similar trend as explained by previous cases for Dhahran and King Abdulaziz street. The percentile level (Figure 4c), the L_{10} also shows 75.3 dB, the L_{90} is 54.5 dB and the L_{50} is 66.3 dB. All readings also exceed the standard limits as similar to cases of other streets. Average measured level of traffic noise level comes to about 87 dBA. The percentile level also shows similar trend, the L_{10} is 84.5 dB, L_{90} is 78.6 dB and L_{50} is 78.6 dB.

The traffic noise profile of twenty eighth street (Pepsi road) shown in Figure 5a, similarly shows consistent trend which generally exceeds 70 dBA, during all the monitoring period. However, at nighttime from 12:00 midnight to 5:32 am the L_{Aeq} level recorded below the 70 dBA. The minimum L_{Aeq} noise level during this duration comes to 56.1 dBA at 3:28 am, and maximum of 82.1 dBA recorded at 4:42 am. Comparisons of noise levels with standards shows that, daytime L_{Aeq} measurements exceed the maximum limit by 13 dB. Similarly, the standards are exceeded by 17 dB during evening and 15 dB at night.

Figure 5b show spectral analysis for the average noise level of twenty eighth street (Pepsi road) also indicates similar trends as previous streets. The percentile levels in Figure 5c, the L_{10} shows 75 dB, the L_{90} is 66.6 dB and the L_{50} is 72.7 dB. Comparing these readings is also shown to exceed Japanese standards for daytime limit of 60 dBA.

Comparing of measured data of traffic noise levels at the different locations in Al-Khobar main roads generally showed a common characteristic of higher level of noise pollution over all measurement locations. The noise profile also shows similar tendency. Dhahran street traffic noise unexpectedly showed higher level than king abdulaziz and Pepsi streets, it was rather anticipated to have a clear reduction in level due to the added width of the street and measurement location beside low traffic lane. The fact that Pepsi street showed higher level than king abdulaziz streets can be explained as due to reduce street width.

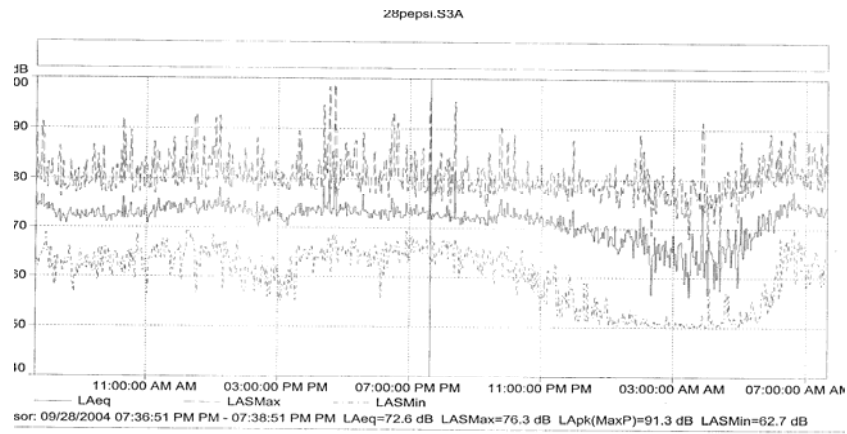


Figure 17 Traffic noise profile of Twenty eighth street (Pepsi street) measured on Tuesday (workday)

Figure (5a): Typical traffic noise profile, illustrated for twenty eighth street (Pepsi road) Street measured on workday.

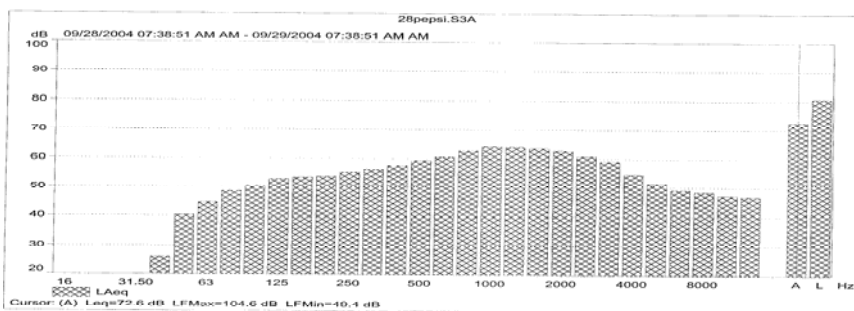


Figure 18 Spectral analysis of traffic noise of Pepsi street

Figure (5b): Typical spectral analysis traffic noise, illustrated for twenty eighth street (Pepsi road) Street measured on workday.

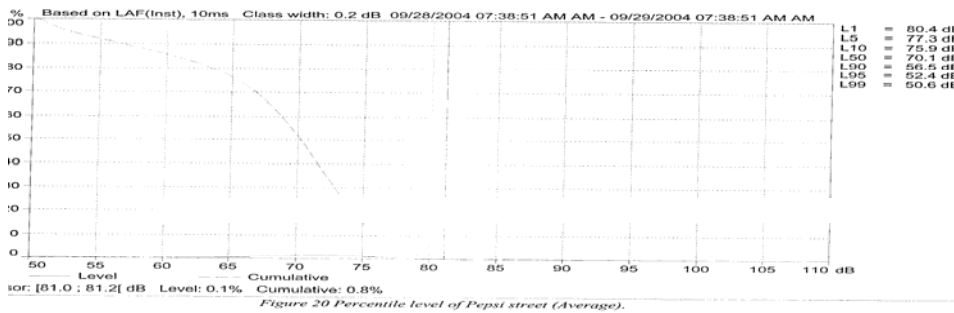


Figure 20 Percentile level of Pepsi street (Average).

Figure 5c- Typical percentile level of traffic noise, illustrated for twenty eighth street (Pepsi road) Street measured on workday.

5 Conclusion

Measurements of traffic noise levels generally show levels in excess of 70 dBA at all locations. These levels are generally higher than accepted standard criteria of maximum permissible level of 60 dBA. As the demand for more transportation anticipated in recent future due to the high growth rate of population in the KSA will evidently worsen the traffic pollution problem. This emphasizes the need for considerations of urgent action in order to limit the traffic noise pollution.

Renovations of most of the major street of Al-Khobar are being carried out by the municipality to accommodate the increasing number of vehicles on the roads. Apparently, this will not solve the problem of noise pollution. However, the following suggestions can be considered:

- Stricter adherence and respect of speed limit assign to the roads.
- Expansion, improvement and encouragement of public transportation.
- Limitation of the number of private cars on roads.
- Revision of driving license regulation specially age wise.
- Use of road texture with low noise generation.
- Enforcement of national noise level standard specifications for imported car.

The limitations of time, manpower and finance was particularly limiting of this study to one city of KSA, Al-Khobar. However, the need to carryout further more investigations of expanded scope over the main cities of the kingdom are of greater importance. Further more, this study confirmed the lack of technical data and statistical information on traffic noise, as well as, the urgent and important need to establish local traffic noise criteria. The establishment of a center for noise pollution monitoring can go along way to over come limitations and address all pertinent aspect of noise pollution control.

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تقييم تلوث ضوضاء المرور لمدينة الخبر كنموذج لأحد مدن المملكة العربية السعودية

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الملخص :

تقدم هذه الورقة مسح وتقييم تلوث ضوضاء المرور لمدينة الخبر. حيث شملت منطقة الدراسة ما مجموعه أربعة شوارع رئيسية وهي شارع الظهران، شارع الملك عبد العزيز، شارع الأمير تركي وشارع الثمانية وعشرون. وقد تم استخدام معيار مستوى ضغط الصوت الموزون - أ للتقييم، ولفترة قياس استمرت 24 ساعة في أغلب المواقع، بالإضافة إلى ذلك تم تقصى تأثير يوم العمل وعطلة نهاية الأسبوع على المستويات المقاسة وأثبتت القياسات وجود تأثير واضح.

وأظهرت النتائج أن معدل الضجيج في شوارع مدينة الخبر تجاوز الحدود القصوى المسموح به للمنطقة السكنية والتجارية لمعظم الأوقات. و شملت الدراسة التحليل الطيفي لمستوى الضغط الصوتي والذي أظهر أن نموذج التدفق الانسيابي لحركة المرور هو المسيطر.

كما أكدت الدراسة الحاجة المستعجلة لتأسيس مركز في المملكة العربية السعودية لمراقبة مستوى تلوث الضوضاء بالمدن الهدف منة المراقبة وكذلك الحاجة لتطوير معايير محلية للضوضاء.