HOW LOUD IS MY BACKYARD?

QUANTIFYING THE VARIANCES IN ENVIRONMENTAL NOISE MONTORING

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1. INTRODUCTION

Environmental noise monitorings are routinely conducted in urban environments in an attempt to determine the noise climate for a given area. The reasons for these monitorings can range from response to residential complaints about various noises (i.e. traffic noise) to pre-development (residential, commercial, industrial) noise climate determination. In almost all cases, it is customary practice to conduct a single 24-hour noise monitoring at one or more locations in the study area. Such a practice raises the question: How accurate is a single 24-hour noise monitoring for representing the typical noise climate in an urban environment? Work has been done in Europe in an attempt to answer this exact question. The purpose of this paper is to provide further information within an Alberta setting. In an attempt to quantify the level of variance, a series of almost thirty 24-hour environmental noise monitorings has been conducted in the backyard of the author. These monitorings were conducted over a period of several months, under various weather conditions and local traffic conditions. In addition, simultaneous monitorings with several different noise monitoring systems (all Type 1) have been conducted to explore variances in equipment.

2. BACKGROUND

The idea and inspiration for this paper is based on a similar, much more comprehensive study conducted in Valencia, Spain by Gaja et al [1]. In this study, noise monitoring was conducted at one of the busiest squares in the City (Plaza de España, with more than 150,000 vehicles per day) with the microphone mounted on a 4m high pole in the center of the square. The noise monitorings were conducted with 15-minute L_{eq}'s (energy equivalent sound levels) over a total period of 5 years from 1996–2000. The purpose of the study was to determine the annual L_{eq} values and investigate how often shorter monitorings were required to equal this annual L_{eq} value. There were several key results from the study:

- The annual L_{eq} values for each of the 5 years differed by only 1 dBA.
- The L_{eq} results from several randomly selected days more accurately reflect the annual L_{eq} than do results from several consecutive days.
- The larger the number of days included in the monitoring, the smaller the error and the higher the probability of the data being within ±1 dBA of the annual L_{eq}.
- The number of random days required for acceptable accuracy was determined to be 9, with 87%, 98%, and 99% accuracy within ±1 dBA, ±2 dBA, and ±3 dBA, respectively.
- The typical deviation with 9 randomly selected days is 0.79 dBA with an 87% accuracy.

3. DESCRIPTION

The environmental noise monitorings were conducted at the residence of the author in the backyard. The house is located on the west end of the City of Edmonton in a predominantly single family dwelling neighborhood with no industrial or commercial districts nearby. The major noise sources include local traffic (within the neighborhood) and traffic on the nearby major roadways (Anthony Henday Drive, Whitemud Drive, Stoney Plain Road). In addition, there was noise from occasional aircraft fly-over's and rail noise from the CN Rail line approximately 4.5km north.

Topographically, the land in the area is generally flat with only minor changes in elevation between the major roads and the noise monitor location. The amount of vegetation is minor with only small sections of scattered trees and short grass. As such, the amount of vegetative sound absorption is considered negligible. Shielding is provided by a slight berm (approximately 2m in height) surrounding the entire community with a standard construction grade 1.83m (6 ft) residential fence on top, along with the many houses within the area.

4. MEASUREMENT METHODS

The noise monitorings were conducted in the backyard, approximately 2/3 the distance between the house and the back fence (approximately 10m from the house), as shown in Fig. 1.

Figure 1. Noise Monitoring Equipment

The following describes the particulars of the measurements:

- All monitorings were conducted for a period of 24-hours.
- The measurements were conducted with a 30-second L_{eq} measuring the broadband Linear, A-weighted, and C-weighted sound levels as well as the 1/3 octave band sound levels.
- A simultaneous audio recording was conducted for the entire 24-hour monitoring period for later post-processing analysis.
- Most of the monitorings were conducted with the same noise monitoring system. In some instances, up to three different systems were used.
- All noise monitoring systems are Type 1, conform to the same ISO and IEC standards, and were re-certified (by a NIST accredited facility) within the previous year.
- All instrumentation was calibrated at the start of each monitoring period and re-checked after each monitoring period to ensure negligible drift.
- The microphone location within the backyard, although generally within 2–3 m each time, was not kept constant. This was done to mimic typical monitoring conditions where slight location variances can occur.
- The monitors, although generally started in the late afternoon, were started at slightly different times every monitoring period. Again, this was done to mimic typical monitoring conditions.
- The monitoring dates ranged from October 2004 to February 2005. Thus, the environmental conditions were generally winter conditions with snow cover and temperatures below freezing (approximately 80% of the monitorings). There was no specific reason for the time period other than the idea was not conceived until late fall 2004 and the data collection had to be completed in time for preparation of this paper in early 2005.
- The monitorings were conducted mainly during the weekday, although some were conducted on weekends and holidays (in particular, Christmas, Boxing Day, and New Years).
- The monitorings were conducted in various weather conditions ranging from clear and calm, to overcast and snowing, to high winds, to very cold (temperatures less than $-20^{o}C$).
- Weather data was obtained from Environment Canada for each of the 24-hour monitoring periods.

In summary, the noise monitorings were conducted with a mind towards gathering data under various conditions (i.e. equipment, location, weather). These various conditions were deemed to be representative of typical noise monitoring scenarios such as having a different person using different equipment on a different day. Thus, it is anticipated (although not specifically proven) that there will be more variation in the results than if all of the measurement parameters are kept the same.

5. RESULTS

The analysis of the results is divided into a few categories. These include:

- Analysis of the broadband dBA and dBC values with both un-modified results and results modified by removal of non-typical noise sources (such as aircraft, rail, construction, etc.) upon review of the simultaneous audio recordings.
- Analysis of the modified 1/3 octave band results during the night-time.
- Analysis of the effects of various monitoring parameters such as wind, temperature, precipitation, day-of-week.
- Comparison of the results obtained by three different noise monitors collecting data at exactly the same time.

5.1 Broadband Sound Levels

The results for the broadband sound levels during weekdays (no holidays) with low wind (less than 15 km/hr), hereafter referred to as "limited data", are presented in Table 1 and Fig. 2. This constitutes a total of eighteen 24-hour periods. The results are presented in un-modified (hereafter referred to as "raw") form and after removal of various non-typical sounds such as aircraft, rail, construction noises.

Table 1. Broadband Sound Levels Obtained During Weekday and Low Wind Conditions

	dBA	dBA(MOD)	dBC	dBC(MOD)
Leq24	43.8	41.9	58.1	56.4
LeqDay	45.3	43.2	59.4	57.6
LeqNight	39.4	38.1	54.7	53.2

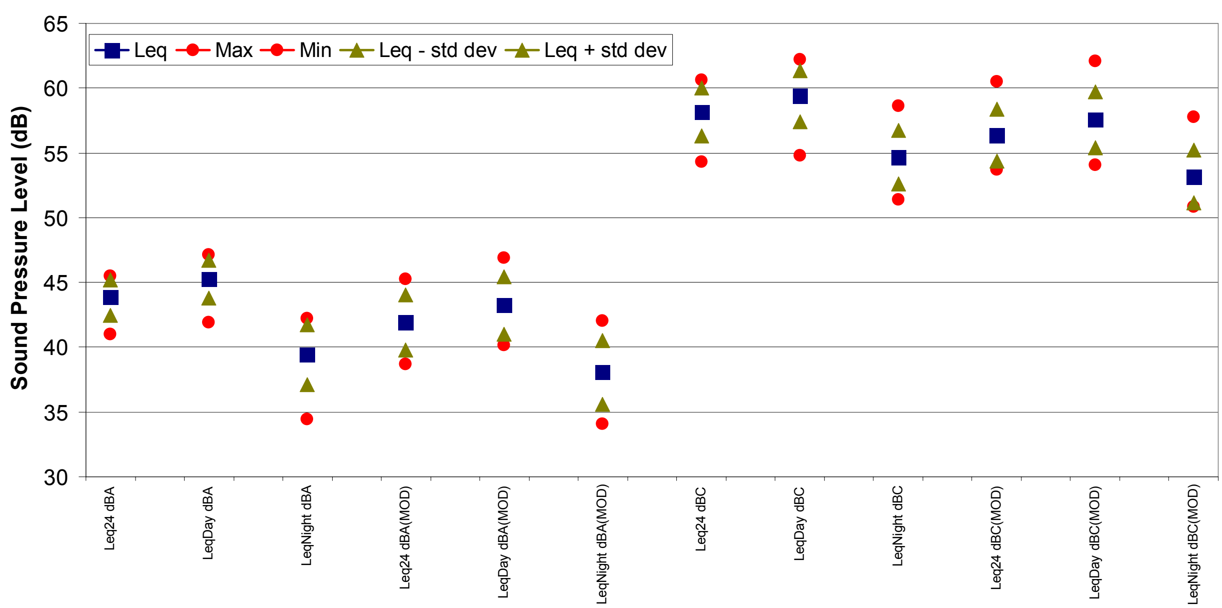

Figure 2. "Limited Data" Broadband Noise Monitoring Results

A review of the data yields the following observations:

- The dBA values for L_{eq}Day and L_{eq}24 resulted in less variance than the L_{eq}Night values. This was not as evident with the dBC values
- There was a slightly larger variance with the modified values than with the "raw" values in both the dBA and dBC results. This is opposite to what would generally be expected, especially given the large variances in sound levels associated with both aircraft noise and rail noise (due to the number of occurrences and various types).
- The overall "raw" L_{eq}Day results were **5.8 dBA** higher than the "raw" L_{eq}Night and the modified L_{eq}Day results were **5.3 dBA** higher than the modified L_{eq}Night.
- The overall "raw" L_{eq}Day results were **4.7 dBC** higher than the "raw" L_{eq}Night and the modified L_{eq}Day results were **4.4 dBC** higher than the modified L_{eq}Night.
- Standard Deviations for all broadband data ranged between 1.4 and 2.5 dB(A&C).
- The day of the week (except weekends) had no noticeable effect on the results.

The results for the broadband sound levels under all conditions (all days of the week and all weather conditions) are presented in Table 2 and Fig. 3. This constitutes a total of twenty-nine 24-hour periods. The results are presented in "raw" form and after removal of various non-typical sounds such as aircraft, rail, construction noises.

Table 2. Broadband Sound Levels Obtained During All Conditions

	dBA	dBA(MOD)	dBC	dBC(MOD)
Leq24	43.3 (-0.5)	41.6 (-0.3)	58.0 (-0.1)	56.8 (+0.4)
LeqDay	44.7 (-0.6)	43.0 (-0.2)	59.2 (-0.2)	58.0 (+0.4)
LeqNight	38.9 (-0.5)	37.7 (-0.4)	54.5 (-0.2)	53.5 (+0.3)

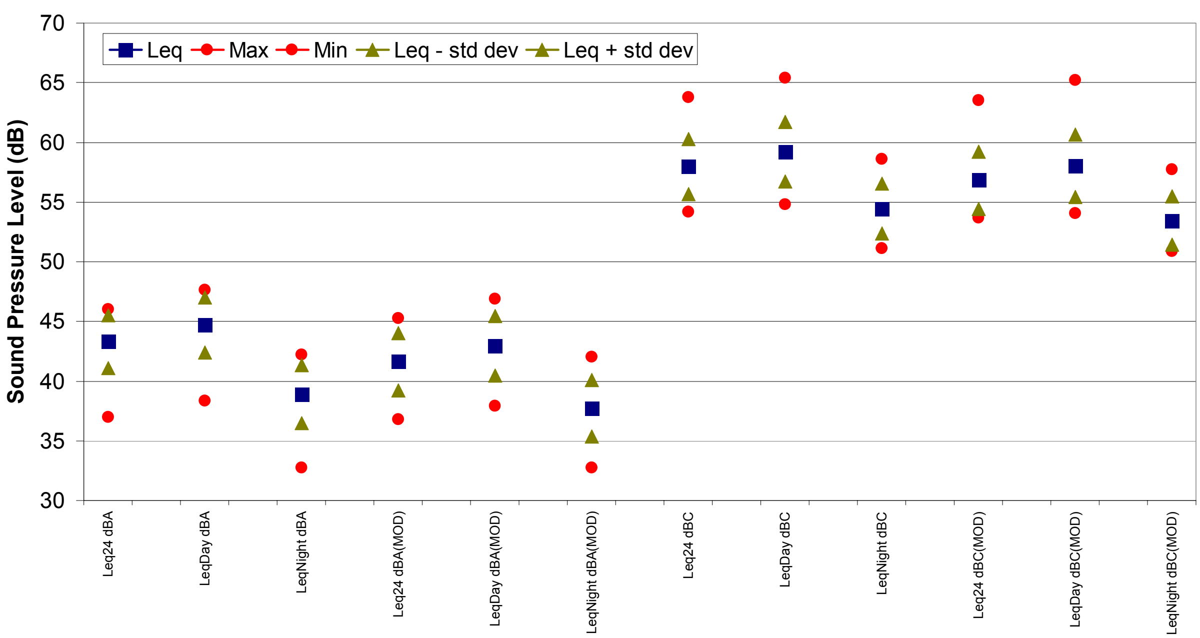

Figure 3. "All Data" Broadband Noise Monitoring Results

It can be seen that there is a slight overall reduction in sound levels by including all data. This is largely due to the decrease in traffic volumes on the weekend and during holidays. The differences, however, differ by much less than one Standard Deviation from the "limited data". In general, the data yields the following observations:

- There is a slightly larger spread in the data compared to the "limited data"
- The differences between L_{eq}Day, L_{eq}Night, and L_{eq}24 are the same as with the "limited data"
- There is a similar spread between the "raw" and modified values, as opposed to the "limited data"
- As expected, the weekends and holidays generally resulted in the lowest sound levels.
- The increase in the modified dBC values is unexplained.

5.2 Night-time 1/3 Octave Band Sound Levels

The results for the night-time 1/3 octave band sound levels for the "limited data" are presented in Fig. 4. The standard deviations range from ±1.3 dB to ±5.3 dB with most values between ±3 dB and are relatively evenly distributed along the entire frequency range (i.e. no one region has a specifically higher or lower standard deviation than the others). In general, this is still quite a large range for differences from one day to the next.

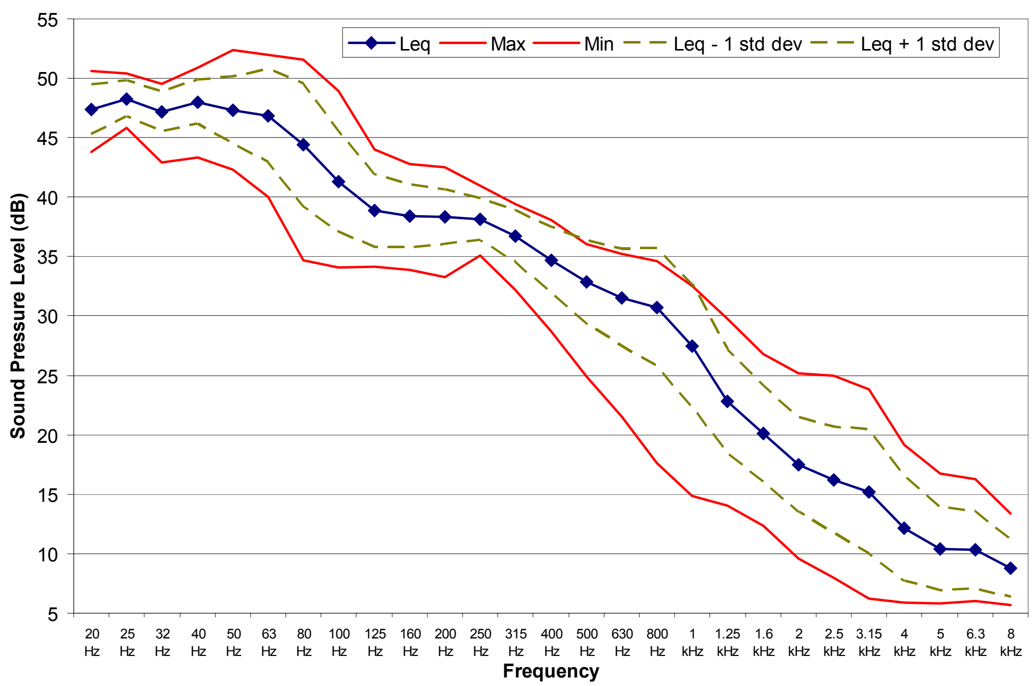

Figure 4. "Limited Data" 1/3 Octave Band Noise Monitoring Results

Figure 5 shows the night-time 1/3 octave band sound levels for all data. It can be seen that, compared to Fig. 4, there is very little difference with the inclusion of weekends, holidays, and high wind occurrences. The standard deviation range is almost identical to the "limited data" case. Even with the higher wind, there is still little change. Again, this is contrary to expectation since high winds generally cause large fluctuations in low frequency noise.

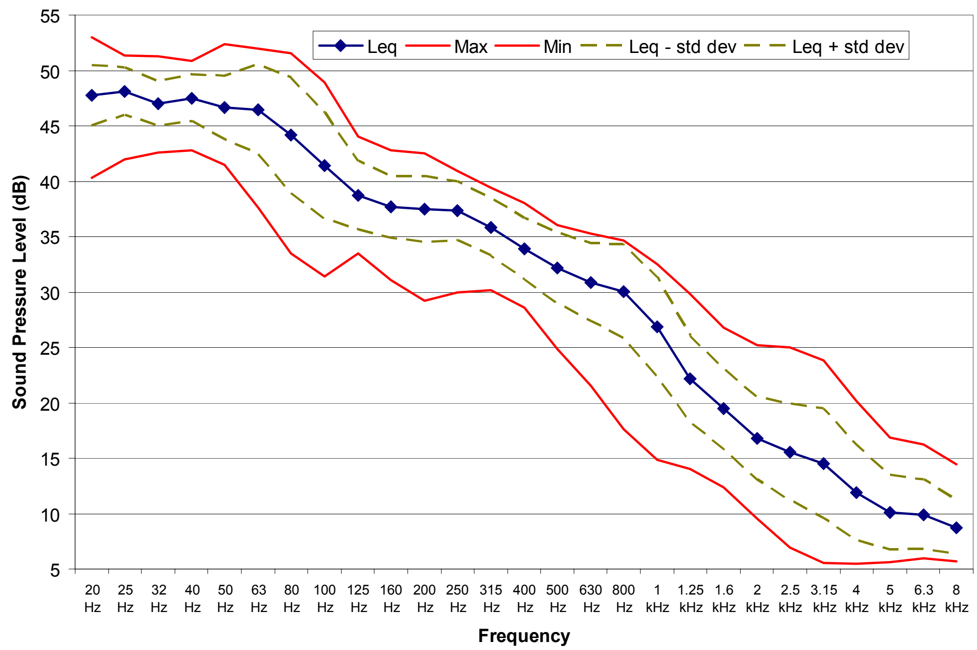

Figure 5. "All Data" 1/3 Octave Band Noise Monitoring Results

A trace of the 1/3 octave band results in Linear, A-weighted, and C-weighted form (with "limited data") is given in Fig. 6. Only the results for the "limited data" case are shown since there is essentially no difference between the "limited data" case and all data included. It can be seen that the broadband A-weighted sound levels are determined largely by the 1/3 octave bands between approximately 160 – 1250 Hz. As expected, the broadband C-weighted sound levels are determined by the low frequency 1/3 octave bands up to approximately 100Hz.

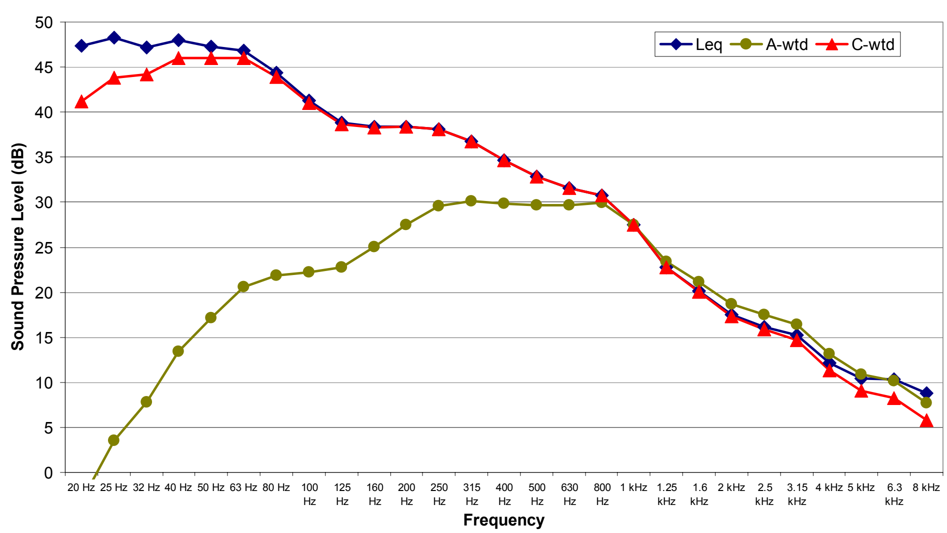

Figure 6. "Limited Data" 1/3 Octave Band Linear, A-Weighted, C-Weighted Results

5.3 Environmental Effects

As mentioned previously, the noise monitorings were conducted with various environmental conditions. In general, the conditions investigated include: wind speed and direction, temperature, precipitation and cloud cover (compared to clear conditions).

Wind Speed and Direction

In general, the wind speed and direction had essentially no impact on the noise levels for all monitoring periods in the "limited data" group. As mentioned previously, this covers all monitorings during the weekday with wind speeds less than approximately 15 km/hr. Detailed review of the data revealed no correlation between wind speed and direction and the broadband dBA and dBC values as well as the 1/3 octave values. Given that the dominant noise sources are generally to the east and southeast of the monitoring location, it was anticipated that there would be lower sound levels with a west wind and higher sound levels with an east wind. This was not observed.

When all of the data is included in the analysis, there is a very tentative trend towards lower sound levels with higher wind speeds (in excess of 20 km/hr). Review of the weather data obtained throughout the study indicated a generally west wind. This was also confirmed through obtaining statistical data from Environment Canada which resulted in a predominant west wind over the last 40 years. Again, given the location of the dominant noise sources relative to the monitor, a west wind would generally serve to lower the sound levels. There were some instances of high wind from the north and south, but none from the east.

Temperature

Similar to the wind speed and direction, there appeared to be little correlation between temperature and sound levels for both the "limited data" and all data. To a very small degree, there was a slight trend towards cooler temperatures resulting in lower sound levels. There was not enough evidence to support this fully however, and it may be that cooler temperatures also have an effect on the total traffic counts. This would be irrespective of the sound propagation, and thus not amenable to drawing any appropriate conclusions. Even if the monitorings are carried out over the summer-time, there may be a noticeable difference in traffic volumes from winter, resulting in similar difficulties in correlating temperature to sound propagation.

Precipitation

Once again, the data does not support a strong correlation between precipitation (in the form of snow during the winter months) and the noise levels. Similar to the wind and temperature comparisons, there seems to be a very tentative trend towards lower sound levels with the presence of snow. This is what one would intuitively expect since there would be a slightly higher amount of absorption in the air and on the ground. There were only a few monitorings which actually occurred during snow-fall, so much more data would be required to make meaningful conclusions.

Cloudy v.s. Clear

Unlike the previous environmental factors which had even a small amount of correlation with sound level, there was no apparent relationship between the amount of cloud cover and the noise climate. The sound levels associated with cloudy and clear periods were evenly distributed between the maximum and minimum levels obtained. The only minor exception to this was with the occasionally slightly lower sound levels obtained while it was snowing (and thus cloudy). As before, more data is required to make better comparisons.

5.4 Equipment Variances

One of the more interesting experiments conducted involved monitoring the 24-hour sound levels with three different noise monitoring systems operating simultaneously. Each of the three systems was set to start and end at exactly the same time (time synchronized to within 1–2 seconds) and perform measurements in the same way (i.e. 30-second L_{eq} with broadband A-weighting and 1/3 octave band data). As stated before all of the systems are Type 1, they meet the same ISO and IEC measurement standards and they were each calibrated prior to the start of the monitoring. In addition, the three systems were located with the microphones less than 1m apart from each other (as shown in Fig. 1).

Figure 7 shows the 1/3 octave band trace for the three systems. Systems #1 and #2 are almost identical while system #3 is slightly higher between 100 – 250 Hz and slightly lower beyond 500 Hz. Systems #1 and #2 are from the same manufacturer with the same model number and similar microphone and pre-amplifier. System #3, however, is from a different manufacturer.

The importance of this figure is to show that different equipment will result in slightly different sound levels. It is impossible to know what the exact sound levels were and it is likely that none of the three monitors are exactly correct. Note that there was a 1 dBA difference in the L_{eq}Night.

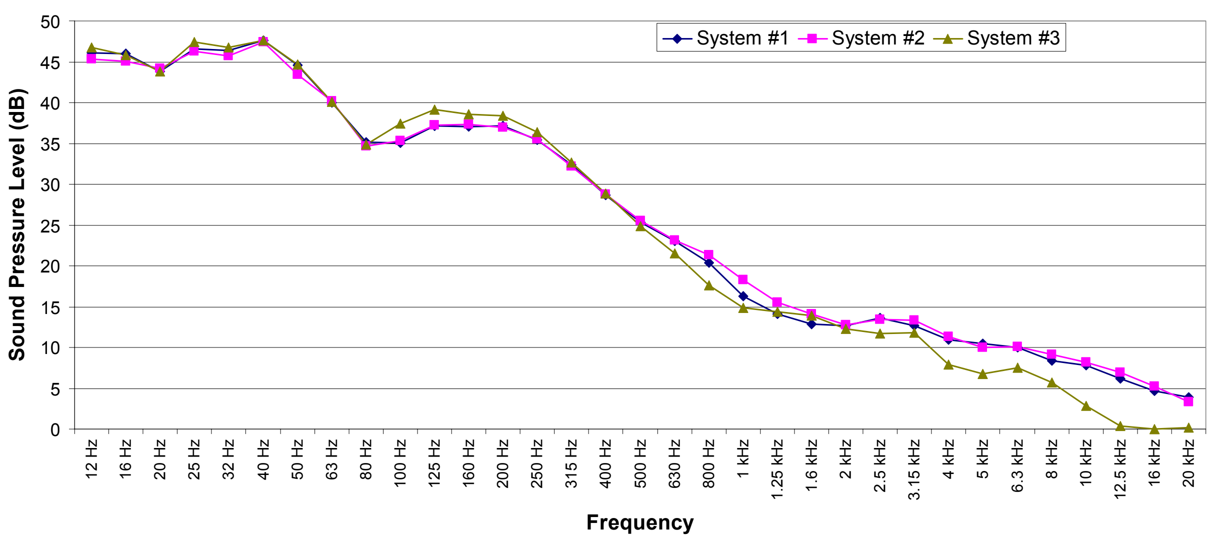

Figure 7. Multi-System 1/3 Octave Band Monitoring Results

6. CONCLUSION

The broadband noise levels obtained from the noise monitorings had a max-min range between ±4.5 to ±8.0 with a standard deviation range between ±1.4 to ±2.5. The 1/3 octave band results indicated larger spreads in both max-min range and standard deviation. In addition, no specific conclusions could be made for various weather factors such as wind speed and direction, temperature, precipitation, and cloud cover. Perhaps this is not so un-expected since there are several noise sources surrounding the receiver location at relatively close distances, as opposed to a rural setting where there is typically only one or a few noise sources which are generally at further distances.

Ultimately, the results indicate that the accuracy of most type 1 sound level meters is beyond that which can be expected from any given 24-hour noise monitoring period. In addition, if a detailed measurement is required for the noise climate within an urban area (not directly adjacent to a major noise source such as a roadway) then a period longer than 24-hours is likely required. Experience has shown that noise levels directly adjacent to major roadways are more consistent and less effected by environmental factors.

REFERENCES

[1] E. Gaja, A. Gimenez, S. Sancho, A. Reig. Sampling techniques for the estimation of the annual equivalent noise level under urban traffic conditions. Applied Acoustics 2003;64:43–53.