MEASUREMENTS AND PREDICTION OF SOUND LEVELS IN QUIET URBAN AREAS - URBAN HUM

Tim Kelsall

Hatch Associates Ltd.
21 St. Clair Avenue East
Toronto, Ontario
M4T 1L9

ABSTRACT

This paper summarises the results of 40 supervised and 23 unsupervised measurements of L_{eq} in urban and small-town backyards. They are used as the basis for a prediction method for minimum equivalent sound levels likely to be found in urban areas.

Community noise is made up of a great many sounds from a large number of different sources: children, dogs, lawn mowers, industry, construction, etc. However, the dominant source of noise in almost every case is traffic. While the level of community noise produced by a multitude of sources would be exceedingly difficult to predict, that due to traffic is less so. In most areas, this sound level due to traffic is close enough to the actual level of community noise that they may be considered identical for practical purposes. While a great deal of work has been done on prediction of sound levels close to busy roads, little has been done to quantify the acoustical environment in quiet areas.

The study described below was designed to explore the background "roar" or "hum" found in residential areas not directly exposed to the noise from traffic on a specific street. The effect of multiple reflections in generating this "urban hum" has been discussed in a review paper by Lyon.[1] It is analogous to the diffuse sound field concept used in architectural acoustics. Large areas of urban communities are found to be dominated by this type of sound, and this "floor" on the propagation of sound from particular streets limits the extent of extrapolation of traffic noise attenuation schemes. Shaw and Olson[2] and later Lyon and Davies[3] derived the background sound level expected in urban areas by modelling the city as a grid of sound sources, ignoring the nearest source and assuming a barrier effect due to buildings. Measurements of this "urban hum" are described below and their variation with time of day and with the population of the town in which they were taken are discussed. This work provides the basis for a table of minimum expected equivalent sound levels (L_{eq}), in a built up community at various hours of the day.

MEASUREMENTS

To study the background sound levels from "urban hum" in residential areas, sites were chosen in backyards of houses fronting on roads with various traffic volumes and in frontyards along streets with very low traffic volumes. The backyard sites were chosen so that no busy street could be seen through a gap larger than 7 m between houses. These measurement conditions are shown to give results dependent on the traffic from any particular road.

Every effort was made to avoid specific sources of sound other than traffic. This restriction determined the two types of measurements taken. Table 1 shows the extent of these measurements.

The first type consisted of twenty minute supervised measurements of the equivalent sound level at a backyard site, in conjunction with simultaneous measurements of the equivalent sound level at 10 m from the centre of the road fronting the lot on which the measurements were taken. They are summarized in Table 2. The frontyard measurements are described in Reference 4.

These supervised measurements provided the best control over unwanted sources of sound. They also helped the measurement team in learning where unsupervised monitors could be placed and provided a check on their results. The choice of a twenty minute measurement period for the study is discussed in Reference 4. The consistency of the 20 minute results, and their agreement with the hourly measurements discussed below, confirms this choice.

Unsupervised monitors were left for 24 hours at locations similar to those described above to give a series of one hour equivalent sound levels. While the microphone **height** in the supervised measurements was 1.2m, the height of the monitors varied, since they were mounted out of reach, in trees or on utility poles. In general, the microphone height was between three and five metres.

The results of the unsupervised measurements are shown in Figures 1 (a & b) for measurements made in Toronto and Orangeville, with populations of 2,000,000 and 10,000 people respectively.

Figure 1(c) shows the results of similar measurements made in seven small towns whose populations varied from 60 to 4000 people.

Where the one hour equivalent sound level measured with the unsupervised monitor exceeded 60 dBA, this measurement was discarded since the results from the supervised monitors indicated that this high a value of L_{eq} was invariably found to be due to sources other than traffic. This only occurred in 5 of the 600 hours monitored.

RESULTS - SUPERVISED DAYTIME MEASUREMENTS

To check that the conditions described above do allow measurements of the "urban hum" or background without the influence of specific streets, an attempt was made to relate front and backyard equivalent sound levels. This attempt gave a regression coefficient of 0.12, i.e. a difference of 10 dB in frontyard L_{eq} generally produced only a 1.2 dB change in backyard L_{eq}. Thus, the L_{eq} in these backyards, which are representative of many backyards, can be taken as being independent of the L_{eq} in their respective frontyards.

Table 2, summarizing the supervised measurements, shows equivalent sound levels in Toronto during the day to be marginally higher in summer than they are in winter. The average measured equivalent sound level in frontyards with very low traffic volumes is less than the average for backyards. Both these results could be due to the small sample size or may reflect different amounts of human activity, other than traffic. The average L_{eq} of 55 dBA shown for frontyards with traffic volumes of between 20 and 60 vehicles/hour is in agreement with the predicted equivalent sound level for these traffic volumes.

RESULTS - UNSUPERVISED MEASUREMENTS

The 24 hour measurements of backyard equivalent sound levels can be used to determine their variation with time of day. Figures 1 (a,b,c) show the hourly average and the standard deviation of one hour equivalent sound levels over a twenty-four hour period. They are drawn from the measurements taken in Toronto, Orangeville, and several small towns. Toronto, with a population of two million, has higher sound levels than Orangeville, with a population of 10,000. This is in agreement with the conclusions of Dixit.[5] However, the backyard sound levels in small towns are between those of Orangeville and Toronto. Similar levels were observed by Dixit in his study of a proposed townsite in a rural area.[6] Our average 24h L_{eq} was 49.5 dBA. His values for 24h L_{eq} ranged from 45 to 53 dBA for comparable sites.

Despite the similarity of results from small towns and from larger ones, it should be noted that the character of sound is quite different. Natural sounds tend to dominate the acoustical environment much more in small towns. For this reason, it would be incorrect to assume that people's reaction to the acoustical environment in large and small towns will be identical just because the equivalent sound levels are similar.

PREDICTION

Figures 2 (a,b) show a linear model of the variation in L_{eq} for different hours of the day. The day is split into three time segments: (i) day time from 07 00 h to 19 00 h; (ii) the period from 19 00 h to 03 00 h when the sound level decreases to a minimum and (iii) the period from 03 00 h to 07 00 h when the sound level returns to its daytime value. It is found that the standard error of estimate from 19 00 h to 07 00 h (of variation from the linear approximation) is reduced from the standard deviation of the hourly equivalent sound levels by at least 1 dB. It becomes similar to the standard deviations measured during the day. Thus, a prediction based on this linear model will have a similar standard error (3-4dB) at all hours of the day. Such a prediction of 1h L_{eq} in urban areas has been prepared based on the above results. It is shown in Table 3.

Daytime values of 50 dBA are assumed based on the results shown in Table 2 for supervised measurements taken in backyards in several towns. It should be noted that unsupervised measurements in Toronto are above 50 dBA. As discussed above, this is considered to be at least partially due to sources other than traffic. Supervised measurements would lie within the standard error of 4 dB.

For the same reason, early evening measurements taken by unsupervised monitors in Toronto are higher than the values used in the prediction. The prediction values are based on a linear model going from 50 dBA during the day to a minimum of 40 dBA at 03 00 h. The standard deviation between the prediction and unsupervised measurements during the night (19 to 07 h) is 3.1 dB and 4.1 dB for Orangeville and Toronto respectively. The average combined deviation is 0.4 dB.

Since many urban residences have at least one face which is protected from the direct sound of traffic from a particular street, the equivalent sound levels in Table 3 often provide a better description of the acoustical environment which residents wish to protect than space-averaged equivalent sound levels or equivalent sound levels taken near individual streets. As such, it is often useful in evaluating the acoustical impact of sound sources on the community.

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TABLE 1

SUMMARY OF MEASUREMENT PROGRAMME

Type of Measurement	Instrumentation	Microphone Locations	Site Locations: No. of Town Sites		Site Locations: Approximate Population	
20 Minute L_{eq} + Traffic Count of Cars & Trucks	-B &K 4424 +30 dB PreAmp -Metrosonics DB 611 Sound Energy Analyzer	1. Backyard-end of backyard away from road. Centre of lot. 1.5 m above ground.	15	Toronto	2,000,000	
			5	Guelph	68,000	
			5	Barrie	33,000	
			3	Milton	18,000	
			3	Markham	53,000	
			2	Georgetown	17,500	
			1	Orangeville	10,000	
			6	Newmarket	24,000	
			40			
Overnight Hourly Measurement L_{eq}	DA 602 Digital Sound Level Monitor	1. Backyard - On tree or telephone pole - 5 m above ground - similar to site for 20 minute measurement.	9	Toronto	2,000,000	Urban
			5	Orangeville	10,000	Small Towns
			14			
			2	Alliston	4,000	
			1	Tottenham	2,500	
			1	Zephyr	340	
			1	Schomberg	1,000	
			2	Mt. Albert	700	
			1	Bondhead	500	
			1	Ivy	60	
			9			

TABLE 2

L_{eq} From Urban Hum

Type of Site	Location	Number of Sites	Average 20 min. L_{eq} (dBA)	Standard Deviation (dB)
Backyards (summer)	Toronto	15	52.3	2.47
	Several Towns	25	50.4	2.27
Backyards (winter)	Toronto	9	50.4	2.88
Front yards 20 vehicles	All	8	49	3.78
Front yards 20-60 vehicles/hour	All	14	55.1	3.02

TABLE 3

Minimum Value for Hourly

L_{eq} by Time of Day

In Urban Areas

Time of Day	L_{eq} (dBA)
07 00 - 19 00	50
19 00 - 20 00	49
20 00 - 21 00	48
21 00 - 22 00	47
22 00 - 23 00	46
23 00 - 24 00	45
24 00 - 01 00	44
01 00 - 02 00	43
02 00 - 03 00	41
03 00 - 04 00	40
04 00 - 05 00	42
05 00 - 06 00	45
06 00 - 07 00	48

Estimated Standard Error: 4 dB

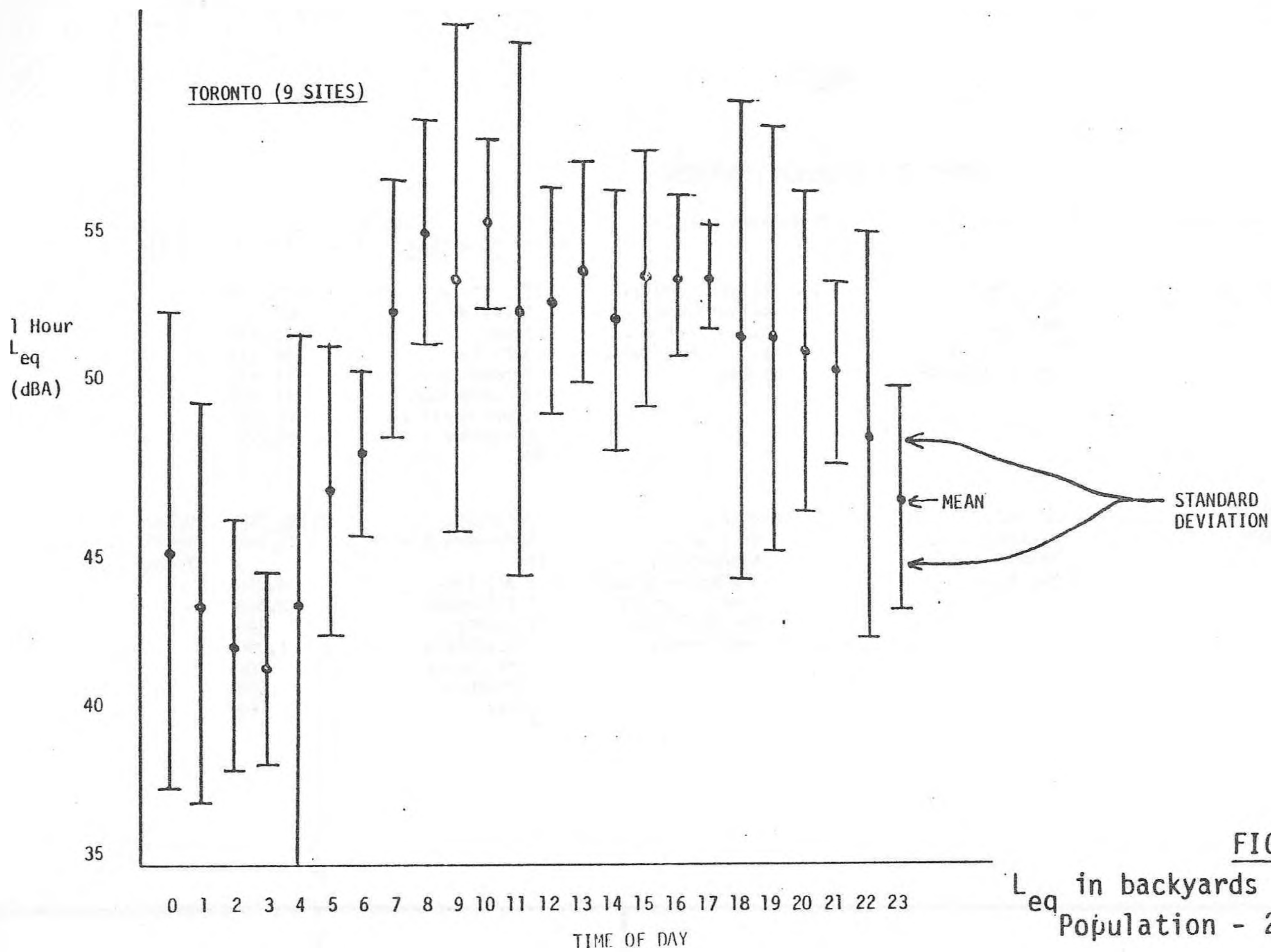

FIGURE 1 a

L_{eq} in backyards in Toronto
Population - 2,000,000.

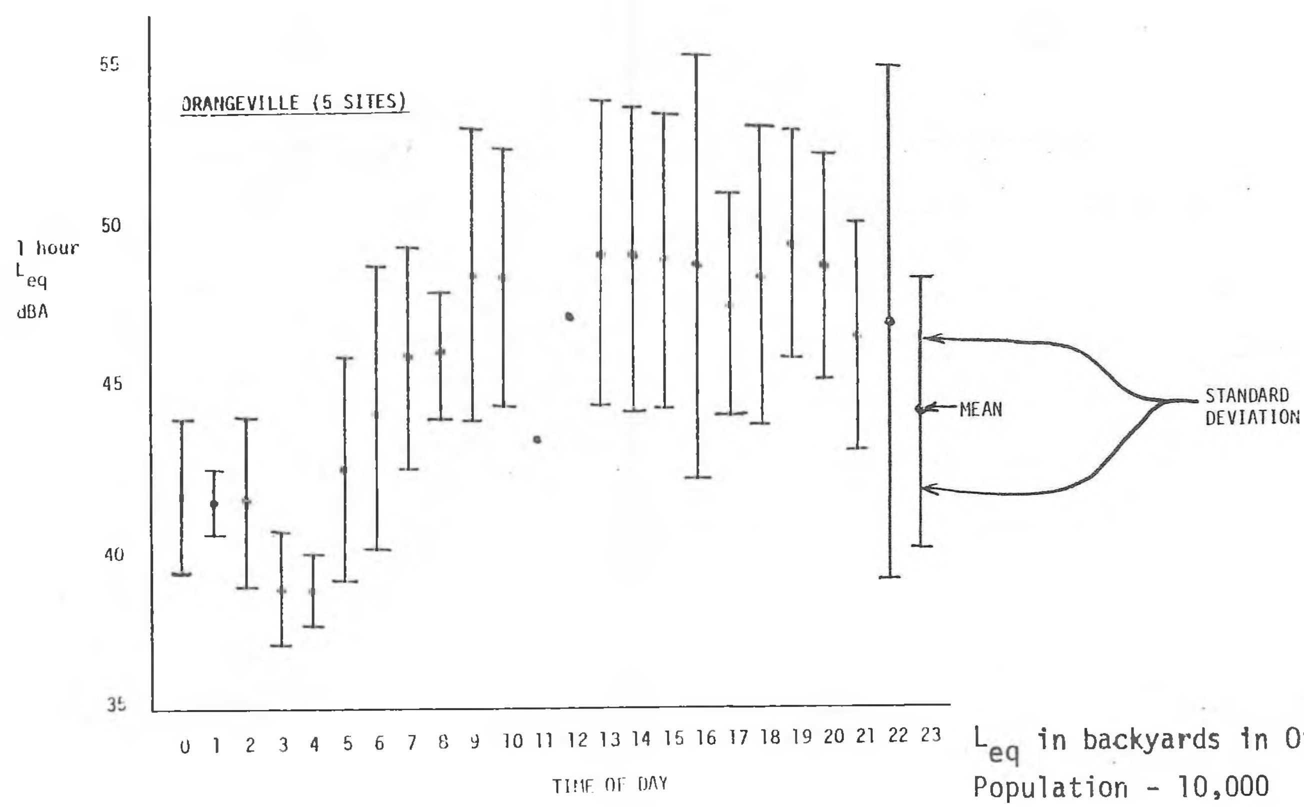

FIGURE 1 b

L_{eq} in backyards in Orangeville
Population - 10,000

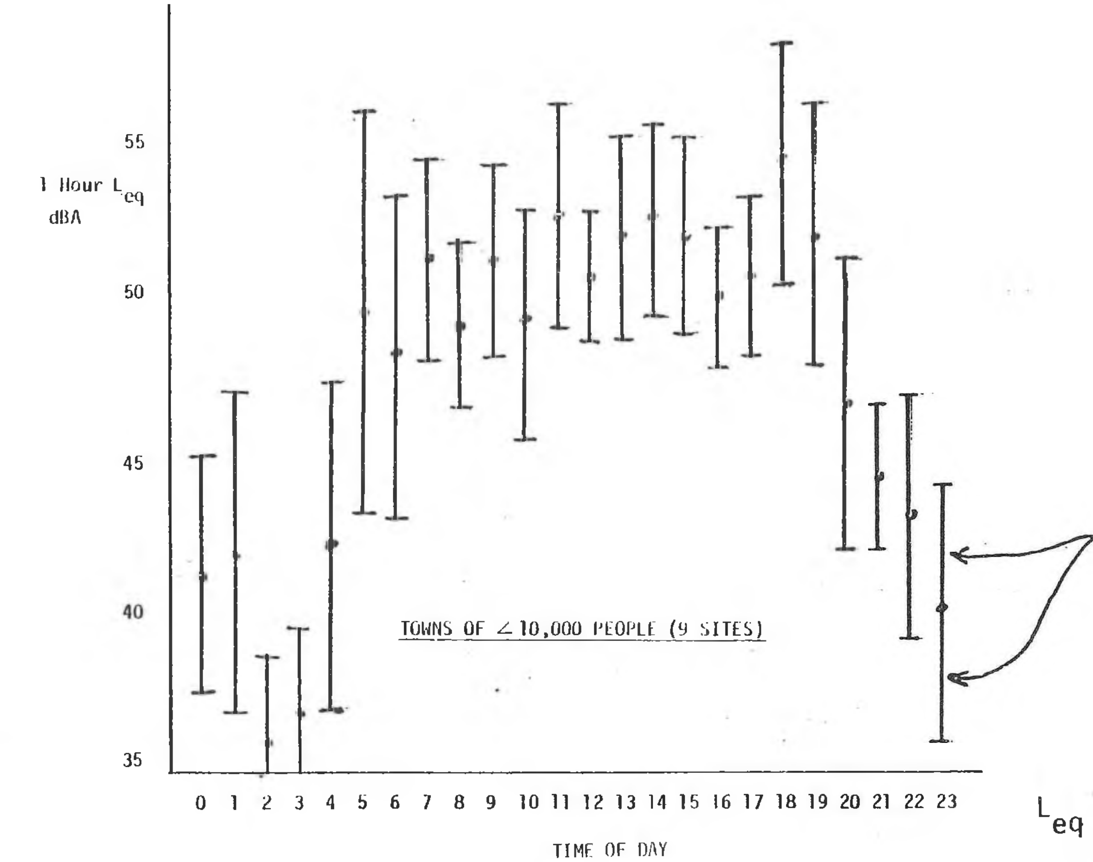

Figure 1 c

L_{eq} in Backyards in Towns population ∠ 10,000

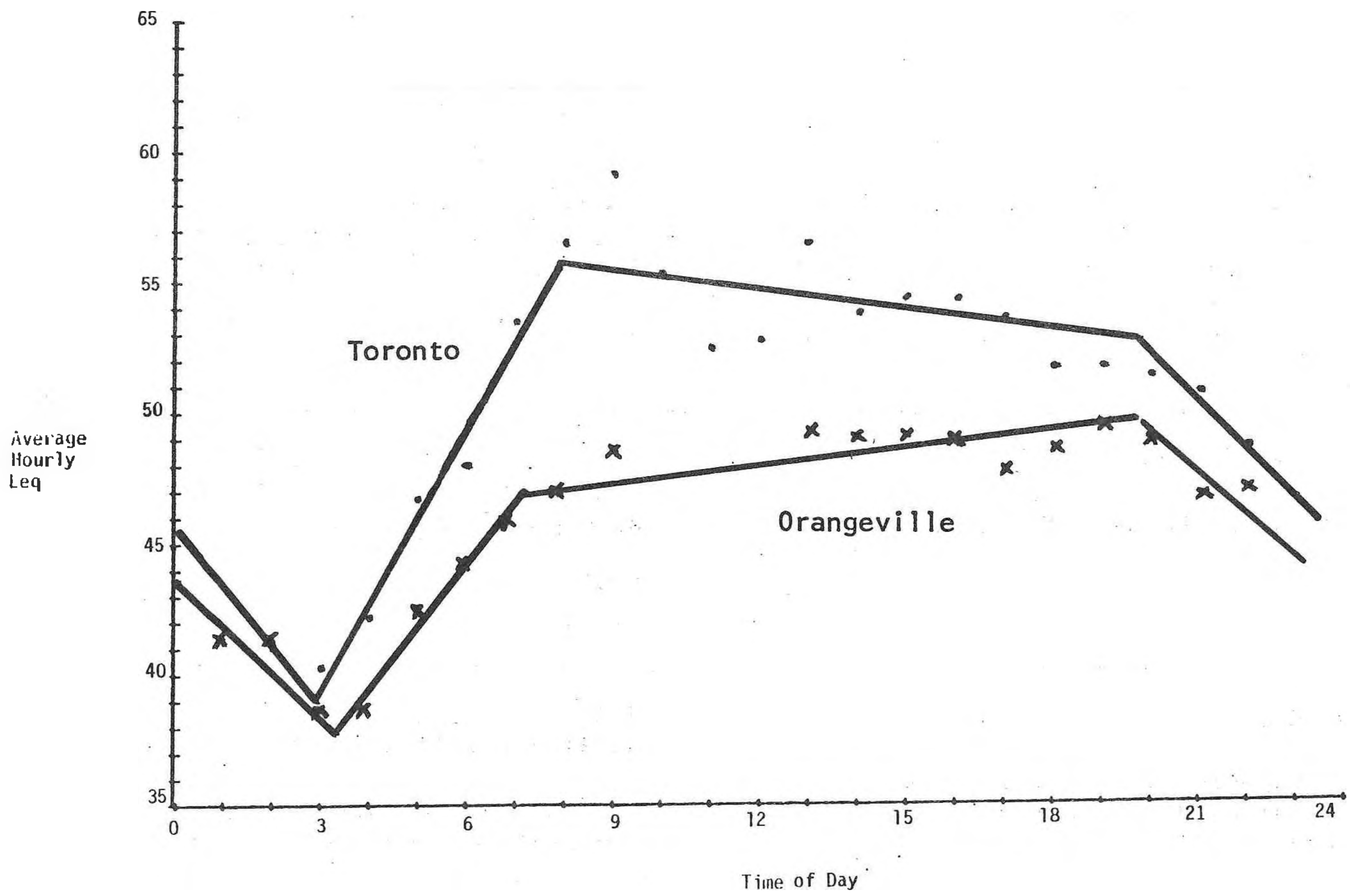

Figure 2. Straight line approximation to variation of hourly L_{eq} with time of day; (a) Toronto, (b) Orangeville