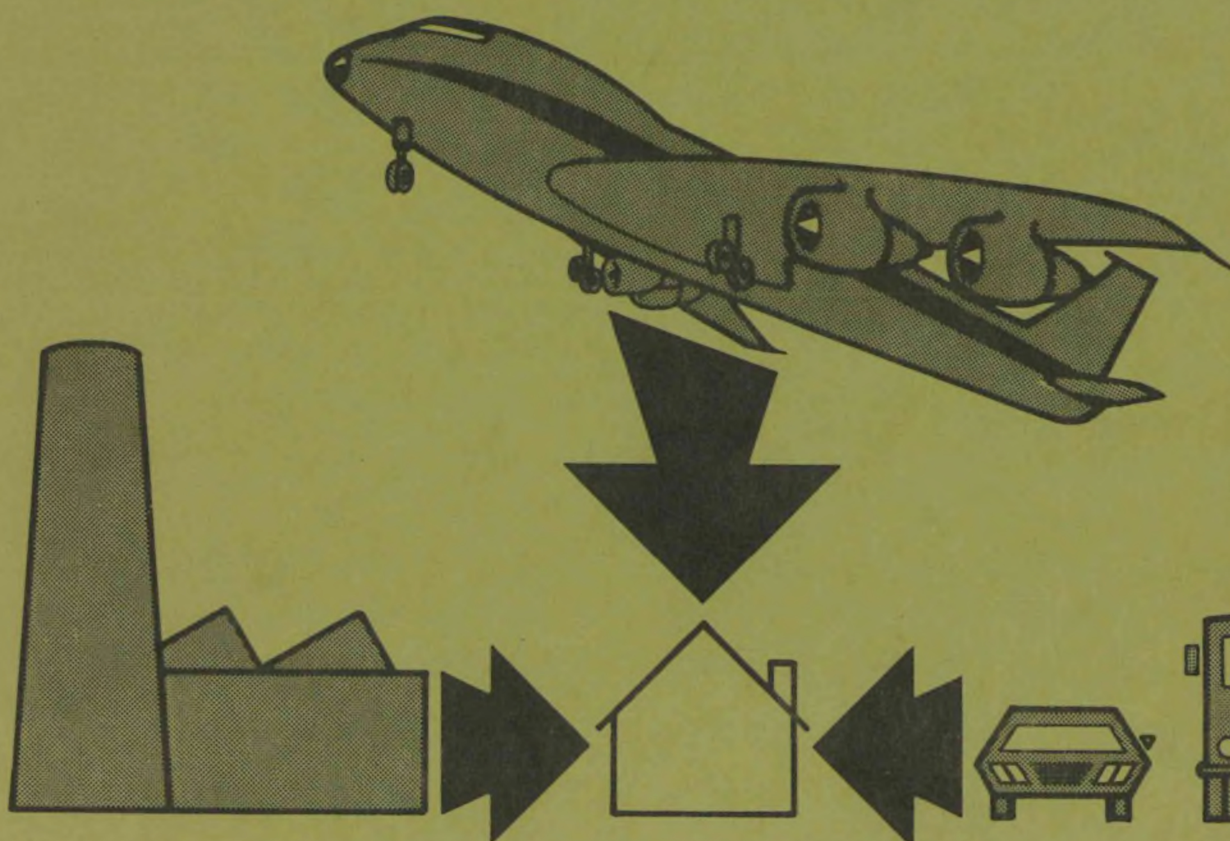
ACOUSTICS AND NOISE CONTROL IN CANADA

L'ACOUSTIQUE ET LA LUTTE ANTIBRUIT AU CANADA

Our cover, by Simon Tuckett, illustrates the paper starting page 6



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CALL FOR PAPERS

The Annual Symposium of the Canadian Acoustical Association will be held in Windsor, Ontario on October 25-26, 1979. The theme this year is:

"THE AUTOMOBILE AND ITS ACOUSTICAL ENVIRONMENT"

Papers on <u>all</u> aspects of acoustics are invited. Abstracts, not more than 100 words in length, describing proposed papers should be submitted before August 1, 1979 for consideration and acceptance by the convenor:

Dr. Z. Reif, P. Eng.
University of Windsor
Department of Mechanical Engineering
Windsor, Ontario
N9B 3P4
Tel: (519) 253-4232, ext. 550

Arrangements for group accommodation have been made at the Wandlyn Viscount Hotel, 1150 Ouellette Avenue, Windsor. Further details of the program and room rates will be mailed separately.

APPEL AUX ARTICLES

Le Symposium Annuel de l'Association Canadienne de l'Acoustique aura lieu à Windsor, Ontario, le 25-26 octobre, 1979. Le theme de cette annee-ci est:

"L'AUTOMOBILE ET SON ENVIRONNEMENT ACOUSTIQUE"

Des articles dans <u>tous</u> les domaines de l'acoustique sont appelés. Afin d'être considérés et acceptés, des résumés de 100 mots au maximum, décrivant des articles à présenter, doivent être remis avant le <u>1er</u> août, 1979 au convocateur:

Dr. Z. Reif, Ing. P.
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Windsor, Ontario
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Des préparatifs pour des logements en groupe sont pris avec l'hôtel Wandlyn Viscount, 1150 avenue Ouellette, Windsor. Des détails supplémentaires sur le programme et les prix de chambres seront envoyés séparément.

THE C.A.A. - WHO WE ARE, WHERE WE LIVE

Our new mailing list is developing quite well. As of writing this article we have over 500 listings. I thought our readers might be interested in the statistics. (Or at least those among you who are demographically minded.)

GEOGRAPHICAL BREAKDOWN

	% of Listing		% of Listing
Ontario	50.70%	Manitoba	2.61%
Quebec	15.60%	New Brunswick	1.20%
Alberta	8.82%	Saskatchewan	0.80%
British Columbia	7.21%	Newfoundland	0.40%
U.S.A.	5.21%	Northwest Terr.	0.40%
Nova Scotia	4.01%	Prince Edward Island	0.20%
Rest of World	2.81%		

FIELD OF BUSINESS

Government	35.1%	Consultants	15.0%
Industrial	24.8%	No category indicated	7.01%
Education	17.0%	Military	1.0%

An interesting statistic:

Those who want direct mail advertisement 89.2% Those who don't 10.8%
(Or who indicated no preference)

Those of you (23%) who didn't mark all the categories may want to know why we wanted that information.

As of this year the association has assumed the financial burden of assembling and distributing the newsletter. We have no subscription charge and no Association membership fee. Therefore, in order to continue to report to those interested in Acoustics in Canada we have developed three methods of obtaining revenue. The first is through a sustaining subscriber drive. For a minimum donation of $10.00 (individuals) or $75.00 (organizations), you can become a sustaining subscriber and have your name printed in the newsletter as a mark of appreciation. The second method of raising money is to solicit advertisements and the third method is to sell our mailing list to commercial interests. Naturally, those persons who indicated a no direct mail preference would not be on the latter list. The statistics will play a big part in our fund raising effort as we believe more people will advertise in our newsletter if they know the type of person that they are reaching.

Finally, I have a request of all of you. Take a minute to look at the mailing label that brought you this newsletter. If you see any errors, clearly indicate the corrections and send it back to me. It is only by obtaining these corrections and change of address notices that we can possibly hope to keep an up-to-date, economical mailing list.

Douglas J. Whicker
Associate Editor

HOUSE OF COMMONS

CANADA

OUR MAN IN OTTAWA

Dr. Tom Siddon, a prominent Canadian acoustician and professor at University of British Columbia, was elected to the House of Commons in last year's by-elections, as the Member for Burnaby-Richmond-Delta. He was also re-elected this May.

The CAA wrote to Dr. Siddon as follows:

> The members of the Canadian Acoustical Association at their annual meeting in Halifax on November 2, 1978 unanimously adopted a motion congratulating you on your recent election to the House of Commons in Ottawa.
>
> We all wish you continued success in representing your constituents and the interests of science in that forum.
>
> In closing, please be assured of our desire to assist and support you in carrying out your duties.

Dr. Siddon replied:

> Thank you for your congratulatory letter of January 29th. The Association was most kind in adopting its motion. It has been a hectic time since my election. The life of a Member of Parliament is filled with excitement, challenges and, often, frustrations.
>
> I look forward to applying my technical perspectives to my new career in Parliament. Only time will tell just how effective I will be in trying to apply scientific and engineering ideals to the chaotic state of affairs which our country faces at this time.
>
> I wish to extend my best wishes to you and the other members of the Association, and I look forward to working with you in the future.

CANADIAN HONOURED ABROAD -

OUR MAN IN NEW YORK

We are proud to report that Tony F. W. Embleton has been voted President-Elect of the Acoustical Society of America for 1979-1980. He succeeds automatically to the Presidency in 1980-81. Tony thereby becomes the second Canadian in recent years to earn this distinction, following on from Edgar Shaw, his colleague at the National Research Council, Ottawa.

Tony Embleton, who has been at NRC for many years and a Principal Research Officer since 1974, has been a pillar of the acoustical communities in Canada and the U.S. In Canada, he has been a leading influence in the Canadian Acoustical Association since its origins in 1961 - as Founding Secretary, 1961-64, and Founding Editor, 1972-75. Less well known is that he is a Fellow of the Royal Society of Canada, an office-holder of the Canadian Association of Physicists, and a Director and Editor of the Youth Science Foundation. He has also been a Visiting Lecturer at the University of Ottawa, and is currently Adjunct Professor at Carleton University.

In the U.S., Tony has been a central figure in the Acoustical Society of America, occupying positions which include Vice President, Associate Editor, Technical Program Chairman, and member and chairman of several ANSI committees. He received the Society's Biennial Award in 1964 and has also won several other American awards - SAE's Arch. T. Coldwell Award in 1974 and Rochester Institute of Technology's John Wiley Jones Award in 1976. Tony has also been a Visiting Lecturer at M.I.T.

Tony Embleton earned a D.Sc. at Imperial College in London in 1964, whereupon Britain's loss was our gain as he rose to exercise his versatile talents over a wide field of acoustics and physics. We hope now that the A.S.A.'s gain will not be Canada's loss, but wish him every success as President-Elect and then President.

D.M.

Avis aux Contribuants

A propos des articles publiés dans le magazine, les Rédacteurs aimerions éviter des exigences d'un format rigide. Mais afin de limiter notre tâche, les contribuants sont invités à utiliser aussi près que possible le format du texte donné à la page 6. Des tableaux ne doivent pas occupés un espace excessif (un bon exemple est donné à la page 27), et les figures doivent être prêtes-à-photographier d'une taille exacte. Généralement, la longueur d'un article ne doit pas dépasser 10 pages. Ça nous fait du plaisir de recevoir vos articles - continuez à les envoyer.

CANADIAN HONOURED ABROAD -

OUR MAN IN LONDON

The Institute of Acoustics (British) has awarded its highest honour, the Rayleigh Medal for 1979 to Dr. Edgar Shaw.

The Rayleigh medal is awarded to persons "Of indoubted acoustics renown for outstanding contributions to acoustics". Dr. Shaw was cited for the degree of excellence he has achieved in many aspects of acoustics, as an experimentor, as an organizer, as a lecturer of outstanding clarity and as a research leader ... He was selected for outstanding contributions to acoustics over a very wide field but with a special interest in the acoustics of the human ear.

Edgar was born in Teddington, Middlesex, England in 1921. His education at the University of London (interrupted from 1940-46 to work as technical officer, Ministry of Aircraft Production), culminated in 1950 when he obtained his Ph.D. from Imperial College.

In 1950 Edgar emigrated to Canada to work at the National Research Council in Ottawa. Since 1975, he has been Head, Acoustics Section, Division of Physics.

Other honours received by Edgar include:

- President, Acoustical Association of America, 1943-74
- Executive Council Member - Committee on Hearing, Bioacoustics and Biomechanics, U. S. National Academy of Sciences, 1973-75
- Chairman - International Commission of Acoustics, 1975 -
- Director of American Institute of Physics, 1979 -
- Secretary of Can. Nat. Comm. for IUPAP, 1979 -
- Fellow, Acoustical Society of America
- Fellow, Royal Society of Canada
- Honorary Member, Canadian Chiefs of Police Association

Edgar and his colleagues at NRC have always been very approachable for consultation with the acoustics community in Canada. In particular they have given a great amount of support to the Canadian Acoustical Association.

On behalf of the CAA, Edgar, our warm congratulations on your award of the Rayleigh Medal.

C.W.B.

Note to Contributors

The Editors would like to avoid rigid format requirements for submissions to the magazine. But to limit our workload, contributors are asked to adopt as far as possible the text format shown on page 6. Tables should not occupy excessive space (a good example is page 27), and figures should be camera-ready and of the right size. Article length should generally not exceed 10 pages. We welcome your contributions - please keep them coming.

COMMUNITY RESPONSE TO AIRCRAFT NOISE IN RELATION TO BACKGROUND NOISE LEVELS

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ABSTRACT

This paper examines the effect of variations in background noise levels on community reactions to aircraft noise using questionnaire and sound level data collected at a stratified random sample of residential sites in the vicinity of Toronto International Airport. The effects of variations in background noise (24 hour L_{eq}) on individual and aggregate responses to aircraft noise are examined. The response variables considered include annoyance, activity interference and complaints. The results of various statistical analyses show that the effect of background level is generally not significant. The direction of the weak effects on individual responses varies by level of aircraft noise exposure and type of response. These findings are compared with those from previous studies.

There are compelling reasons to believe that community response to intrusive noise such as that from aircraft is *not* independent of background noise levels. It seems intuitively reasonable to suppose that the impact, however defined, of the intrusive noise will show a relative decrease as background levels increase. If such a relationship exists, measures of noise impact which fail to account for background noise conditions are suspect. On these grounds the adequacy of NNI and NEF as measures of aircraft noise exposure and by extension of noise impact can be questioned. Neither index incorporates information pertaining to the background noise levels against which the aircraft noise is experienced.

Johnston and Haasz (1978, p.1) argue that the need for explicit recognition of the effect of background noise levels has increased due to reduction in the noise generated by aircraft resulting from technological advances over the past decade. The consequences of this reduction is that aircraft noise is less likely totally to dominate the noise environment even in areas quite close to airports. Clearly, with increasing distance from an airport, the degree to which aircraft noise is dominant declines and the potential influence of background noise increases. Whereas the interaction between intrusive and background noise levels can be estimated quite easily in purely physical terms, the problem is more complex where the concern is to estimate the effects of the interaction in terms of changes in the impact of the intrusive noise on the community.

In this context, this paper examines the effect of background noise levels on community response to aircraft noise in the vicinity of Toronto International Airport. The analysis is based on questionnaire data and sound level measurements collected at 56 residential sites randomly selected within 4 NEF zones. The effect of background noise level on individual and aggregate response to aircraft noise are considered. The paper begins with a synthesis of the findings of previous studies. A description of the data follows. The analysis is then outlined and the results are discussed. Finally, a brief summary is presented.

PREVIOUS FINDINGS

The two studies most closely related to the present one are those of Powell and Rice (1975) and Johnston and Haasz (1978). Both studies explicitly examined the effects of background noise level on judged annoyance of aircraft noise. They differ from this study in that both were conducted in a laboratory setting. The extent to which the findings of laboratory research can be generalized to real world conditions remains an open question.

Powell and Rice found that average annoyance due to individual flyover events decreased with increasing background level when the background level was held continuous over a laboratory session. For variable background conditions, however, no such trend was observed. Based on regression analysis, the equivalent reduction in aircraft noise level by moving from lowest (mean = 32.3 dB(A)) to highest (mean = 46.4 dB(A)) continuous background noise levels was 4.9 dB. With reference to earlier studies, Powell and Rice find this reduction in close agreement with that reported by Pearsons (1966) and contrary to the larger equivalent reduction reported by Nagel *et al.* (1967). Analysis of the effects of background noise level on annoyance scores averaged over the various flyover events yielded inconclusive results. Contrary to the findings for the individual flyovers a small but non-significant increase in average annoyance was observed with increased background level. In conclusion, Powell and Rice recognize the need for field study data to complement and supplement laboratory research. Field study data are not only potentially more realistic but also permit analysis of the effects of background noise level on long-term exposure to aircraft noise.

In the Johnston and Haasz study, each of 35 jurors made an annoyance judgement for each of six flyover events, under four differing conditions of background traffic noise and three differing signal durations. Regression analysis revealed that background noise had a significant effect on annoyance scores for the two shorter signals (22 and 44 seconds). The effect of background noise for the longest signal (88 seconds) was not significant. Consistent with Powell and Rice's findings, the direction of the significant effects was such that increasing background levels was associated with reduced annoyance scores. Johnston and Haasz estimate that under conditions where the background traffic noise is of substantially longer duration than the flyover events and where the mean background level is equal to the peak indoor aircraft level, the equivalent reduction in aircraft noise is in the range of 5-6 dBA.

The results of these two studies are in general consistent, showing that background noise level has a significant influence on the judged annoyance of *single* flyover events as experienced within the laboratory situation. In the real world situation we are generally more interested in the effects of background noise level on subjective response to aircraft noise over a prolonged period of exposure. It is uncertain to what extent the findings of these laboratory studies can be generalized to that situation. The finding reported in the Powell and Rice study that background noise had a non-significant effect on annoyance averaged over a set of flyover events is possibly the one most relevant to real world conditions.

The effect of background noise on reaction to aircraft noise has been examined in at least two field surveys (Bottom, 1971; Grandjean *et al.*, 1976). Using McKennell's Guttman scale, Bottom obtained annoyance scores from 35 residents at each of 9 sites combining three different NNI levels (60, 45 and 25) and three levels of traffic flow (over 32,000 vehicles/day, 19,000 vehicles/day and access traffic only). Plotting the relationship between mean annoyance against NNI for each level of traffic flow separately, showed that, for any given NNI, annoyance was greater the lower the traffic flow. A two-way analysis of variance revealed both factors - NNI and traffic flow - as having a statistically significant effect on annoyance scores. When general noise dissatisfaction was used as the dependent variable within a second analysis of variance, the effect of NNI was significant as was the interaction between NNI and traffic flow. Traffic flow itself was not found to have a significant effect. Bottom concludes that NNI is not the best predictor of either aircraft noise annoyance or total noise dissatisfaction and he supports the use of Robinson's L_{NP} index (Robinson, 1971) gives its applicability to conditions involving a mix of noise sources.

As part of a major survey of the effects of aircraft noise around three airports in Switzerland, Grandjean *et al.* collected traffic noise measurements around the Basle airport. Using questionnaire data collected from 944 residents, they report a marked decrease in complaints about aircraft or aircraft noise with increased traffic noise. Although no statistical analysis is reported, they conclude that "the surrounding noise is relevant to the disturbing effect of aircraft noise" (p.87). Unfortunately no mention is made of the effect of traffic noise levels on responses to aircraft noise other than complaints.

The results of neither of these two field studies are conclusive. In Bottom's study the data set is quite limited; in the Swiss study the data set is larger but few results relating to the effects of background noise are reported and no statistical analysis was performed. Considered together the findings from these different studies provide some support for the intuitive expectation that background noise levels significantly influence subjective response to aircraft noise. However, the extent and perhaps even the existence of this influence under real world conditions remains uncertain.

DATA DESCRIPTION

The data used in this analysis were collected at 56 residential sites selected by means of a stratified random sample of block faces around Toronto International Airport. The sites are located in one of three NEF zones (30-35, 25-30, <25) and represent a range of background noise levels due primarily to road traffic (24 hour L_{eq} ranges from 49 to 72 dBA). At each site 12 to 15 household interviews were completed using a structured questionnaire. The questionnaire was introduced as a neighbourhood attitude survey and began with general questions about the neighbourhood leading on to more specific questions about the sounds noticed in the neighbourhood and the impacts of each sound reported as disturbing. The impact measures included annoyance, activity interference, health effects and complaints. A total of 673 interviews was completed. 88 percent of the respondents mentioned hearing aircraft and 74 percent were to some degree disturbed by aircraft noise.

24 hour sound level measurements were taken at each site. A record was kept of the sound levels (L_{eq}) for each flyover event. These were accumulated for each hour and subtracted from the overall L_{eq} for that hour to provide a measure of the background L_{eq}. For this analysis the background hourly L_{eq}s were accumulated to give a 24 hour L_{eq}.

For analysis purposes the questionnaire data can be used in both a disaggregate and aggregate form. In the former case, the data comprise each subject's responses to a specific noise source, in this case aircraft. In the latter case, the data are aggregated for each of the 56 sites and expressed in terms of the percentage of subjects at a site reporting a particular response.

ANALYSIS

Statistical analysis of the effects of background noise levels on responses to aircraft noise was performed using both the disaggregate and aggregate data.

Disaggregate Analysis

The disaggregate analysis involved comparing the responses of residents exposed to the same level of aircraft noise but different levels of background noise. This was achieved by grouping respondents by NEF (30-35, 25-30, <25) and performing separate tests for each of the three groups. Twelve different response variables were examined comprising various measures of aircraft noise annoyance, activity interference, health effects and complaint action. Annoyance ratings examined were an overall rating on a 9 point bipolar scale (ranging from *extremely agreeable* to *extremely disturbing*) and ratings on an 11 point unipolar scale (0 = not all disturbing to 10 = unbearably disturbed) for different combinations of location (inside or outside) and time of day (day, evening or night). Also examined were mentions of speech interference, volunteered and any sleep interruption, increased tension, and complaints. The relationship between the bipolar rating and background level was tested using non-parametric correlation (Kendall's Tau). Tests of relationships involving the unipolar ratings were based on Pearson's correlation (r). The relationships between the remaining responses and background level were examined by a difference of means test (student's t statistic).

The test results (Table 1) show that only 8 of the 36 relationships examined were statistically significant. Two of these were in the NEF <25 groups, 5 in NEF 25-30, and 1 in NEF 30-35. Six of the significant relationships involve the annoyance scales. Reporting of speech interference and complaint action was significantly related to background level in the lowest NEF category.

Examination of the direction of the relationships reveals some inconsistency. For the NEF <25 group, the relationships are such that the reporting of speech interference and complaints is associated with lower background noise levels. In the case of speech interference, this finding can probably be explained by the fact that only at lower background noise levels would the relatively low aircraft noise (NEF <25) be sufficiently intrusive to impair communication. In contrast, the significant relationships in the higher NEF categories are in the opposite direction; aircraft noise was rated as more disturbing the higher the background noise level. This finding is contrary to previous studies. Closer examination of the data revealed that the significant relationships for the NEF 25-30 group could be attributed to the annoyance ratings at the site with the highest background level. When this site was removed none of the relationships were significant. The overall conclusion drawn from the disaggregate analysis is that background level does not have a consistent or clearly significant effect on individual level response to aircraft noise.

Aggregate Analysis

Regression analyses were performed to examine the effect of background level on aggregate response to aircraft noise. Three aggregate response variables are considered: percent highly disturbed, percent reporting speech interference and percent having complained. These three variables reasonably represent the types of response variable included in the analysis and are variables commonly employed in previous studies of community response to noise. Percent highly disturbed was defined as the percentage of respondents who rated aircraft noise either "considerably" or "extremely disturbing" on a 9 point bipolar scale ranging from "extremely agreeable" to "extremely disturbing". Percent reporting speech interference was based on the percentage reporting interference in one or more of the following speech related activities: conversing indoors, conversing outdoors, watching television, speaking on the telephone. Percent having complained represents the percentage having contacted one or more of several agencies (e.g. the noise source, the police, some level of government) to complain about aircraft noise. These aggregate variables were calculated for each of the 56 sites.

The regression analysis was conducted in two ways. First, the 56 sites were divided into two groups based on background level. Separate regressions were performed for each group and the slope and intercept parameters were compared. Second, the 56 sites were treated as a single set and multiple regression equations were calculated with the aircraft and background noise levels as the two independent variables.

The two groups of sites for the first approach comprised those (16 sites) at which the background level exceeded 60 dBA (24 hour L_{eq}) and those (26 sites) where the background level was less than 57 dBA (24 hour L_{eq}). Sites with background levels between 57 and 60 dBA (24 hour L_{eq}) were excluded. The purpose of this grouping was to separate sites with relatively high and low background levels.

For each site group three equations (Table 2) were calculated by regressing the three aggregate response variables against aircraft noise level (24 hour L_{eq}). The equations for the same response variable were compared by first testing for differences in the slope coefficients according to the following formula:

$$t = \frac{b_1 - b_2}{s(\hat{y})_p \left(\frac{1}{\sum_i (x_{i1}-\bar{x}_1)^2} + \frac{1}{\sum (x_{i2}-\bar{x}_2)^2} \right)^{\frac{1}{2}}}$$

with $(N_1 - 2) + (N_2 - 2)$ degrees of freedom,

where b_1 = the slope of the regression line for the first subgroup

$\sum_i (x_{i1}-\bar{x})^2$ = the sum of squared deviations about the mean of the independent variable in the first sub-group,

$s(\hat{y})_p = [s^2(\hat{y})_{pooled}]^{\frac{1}{2}}$,

$$s^2(\hat{y})_{pooled} = \frac{(N_1-2)s^2(\hat{y}_1) + (N_2-2)s^2(\hat{y}_2)}{(N_1-2) + (N_2-2)}$$

$s^2(\hat{y}_1)$ = variance of the estimate of the dependent variable for the first subgroup, and

N_1 = the number of observations in the first subgroup,

N_2 = the number of observations in the second subgroup.

None of the t statistics are significant at the .05 level. We conclude therefore that the slopes of the paired regression lines are not significantly different.

Under the assumption of no significant difference in slopes, a pooled estimate of the slope was calculated and a test for differences in intercepts was performed. This involved calculating a regression equation for each response variable including a dummy independent variable to represent the background level (0 = background <57 dBA; 1 = background >60 dBA). The dummy variable did not make a significant contribution to any of the three equations (Table 2) leading to the conclusion that the intercepts are not significantly different. In other words, there is no significant difference in the aggregate response to the same level of aircraft noise between sites with high and low background levels.

The second approach to the regression analysis treated the background level as a continuous variable. Two steps are again involved to test: first, whether the background level significantly affects the rate of change in response to aircraft noise (i.e. is there an interaction effect?); and second, whether the level of response is significantly affected by the background level (i.e. is there an independent effect?). The first test involved calculating regression equations containing three terms entered in the following order: the aircraft noise level (24 hour L_{eq}); the cross product of the aircraft and background levels; and the background level (24 hour L_{eq}). In none of the three equations was the explained variation (R^2) attributable to the cross product term significant (Table 3). This shows that the background level does not affect the rate of change in response to aircraft noise. A second set of equations was calculated (Table 3) excluding the cross product term. The contribution of the background level in these equations was not significant leading to the conclusion that the level of response to aircraft noise is not affected by the background noise. In the equations for percent highly annoyed and percent reporting speech interference, the regression coefficients for aircraft L_{eq} are significant. This is not the case for percent complaining underlining the difficulty of predicting of complaint action.

The results of both approaches to the regression analysis are consistent. Background level does not significantly effect either the rate of change in response to aircraft noise or the level of response. These findings reinforce the conclusions of the disaggregate analysis. From these data therefore there is a strong basis for concluding that background levels do not significantly effect either individual or aggregate responses to aircraft noise.

DISCUSSION

It is now appropriate to compare these findings with those of the previous studies described earlier. Firstly, compared with the laboratory studies of Powell and Rice (1975) and Johnston and Haasz (1978), this analysis has not shown background levels to have as significant an effect on reactions to aircraft noise. But the comparison is hardly a fair one given that the significant effects of background levels observed in both laboratory studies were on reactions to individual flyover events and not long-term exposure to aircraft noise which was the focus of this analysis.

As noted earlier, in so far as these laboratory studies provide any indication of the effects of background noise levels on longer term exposure, they suggest that the effect is weaker than for individual flyover events and quite possibly non-significant. The present findings are clearly in general consistent with this suggestion.

Comparison with Bottom's study (Bottom, 1971) is complicated by the fact that he used different metrics from those used in this analysis to measure both aircraft and background noise levels. In addition, the background conditions represented in his data are limited to only three levels of traffic flow. Allowing for these differences, it seems likely that the present findings are not consistent with Bottom's results. The significant effect of background levels that he reports is not confirmed by our data. Comparison with Grandjean's results (Grandjean *et al.*, 1976) is also difficult because his findings are limited to the effects of background levels on aircraft noise complaints and further because no statistical analysis is reported. Again, allowing for these difficulties, it appears that our results for percent complaints show neither as strong nor as uniform an effect of background levels as those reported by Grandjean.

Considered overall the results of this analysis do not support the research hypotheses implicit in the introductory section of the paper. The null hypothesis that reactions to aircraft noise are independent of background levels cannot be rejected with the normally required level of confidence. It follows from this that measures of noise exposure such as NEF and NNI are not insufficient on the grounds that they fail to account for background levels. As predictors of noise impact they may of course be insufficient on other grounds and the relatively weak relationships observed in these data between NEF and the response variables certainly suggest this.

Allowing for the weak effects of background level overall, the research hypothesis concerning the direction of the effect also lacks support. The expectation that for a given exposure level, the impact of aircraft noise will decrease as background levels increase does not hold for all levels of exposure. To the extent that conclusions can be drawn from the weak relationships observed using the disaggregate data, the effect of background level on aircraft noise response changes, such that where the intrusive level is relatively low (NEF <25) higher background levels do as expected lead to a reduced impact, but where the intrusive level is higher (NEF 30-35) higher background levels are associated with increased impact.

SUMMARY

This paper has examined the effects of background noise levels on community response to aircraft noise. Previous detailed investigation of this topic has been based primarily on analysing subjective reactions to individual flyover events under laboratory conditions. The extent to which the findings of these studies apply to community responses to aircraft noise over an extended time period under real world conditions is uncertain. The questionnaire and sound level data used in this analysis were collected

at 56 sites within four NEF zones around Toronto International Airport. Statistical analysis of individual and aggregate responses to aircraft noise leads to two main conclusions. First, the effect of background level is generally not significant. Second, the direction of the effect on individual responses is not consistent. High background levels tend to reduce the speech interference and complaint responses, but to accentuate annoyance.

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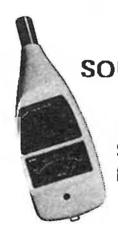

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Table 1

Significant Effects of Background Noise Level

on Individual Responses to Aircraft Noise

Variable	NEF <25	NEF 25-30	NEF 30-35
Bipolar	-	tau=.1167*	tau=.1102*
Unipolar ratings			
indoors, day	-	r=.1489*	-
outdoors, day	-	r=.1763**	-
indoors, evening	-	-	-
outdoors, evening	-	r=.1857**	-
night	-	-	-
overall	-	r=.1877**	-
Activity interference			
speech	t=2.47*	-	-
sleep (vol)	-	-	-
sleep (any)	-	-	-
Nervousness	-	-	-
Complaints	t=2.08*	-	-

\- not significant at .05 level

* significant at .05 level

** significant at .01 level

Table 2

Effects of Background Noise (Dichotomized Variable) on Aggregate Response to Aircraft Noise

Response variable	R^2	Std. Error
Test for differences in slope coefficients:		
% highly annoyed		
low background: $\%HA = -76.5 + 1.838 \text{ AC } L_{eq_{24}}$	.236	13.179
high background: $\%HA = -190.2 + 3.845 \text{ AC } L_{eq_{24}}$	.367	20.766
difference in slope coeffs. = -2.007; t = -1.48; df = 38; prob. = 0.15		
% speech interference		
low background: $\%SI = -142.3 + 3.330 \text{ AC } L_{eq_{24}}$	.377	17.066
high background: $\%SI = -238.1 + 4.810 \text{ AC } L_{eq_{24}}$	.491	20.159
difference in slope coeffs. = -1.48; t = -0.98; df = 38; prob. > 0.3		
% complaints		
low background: $\%C = -14.8 + 0.484 \text{ AC } L_{eq_{24}}$	.013	16.926
high background: $\%C = -122.4 + 2.091 \text{ AC } L_{eq_{24}}$	.249	14.963
difference in slope coeffs. = -1.607; t = -1.20; df = 38; prob. > 0.2		
Test for differences in intercepts:		
% highly annoyed		
$\%HA = -123.4 + 2.609^{***} \text{ AC } L_{eq_{24}} + 6.68^{NS} \text{ BACK}$	.284	16.637
% speech interference		
$\%SI = -176.9 + 3.898^{***} \text{ AC } L_{eq_{24}} - 7.05^{NS} \text{ BACK}$	.458	18.256
% complaints		
$\%C = -52.4 + 1.101^{NS} \text{ AC } L_{eq_{24}} - 1.17^{NS} \text{ BACK}$	.073	16.320

*** significant at .001 level

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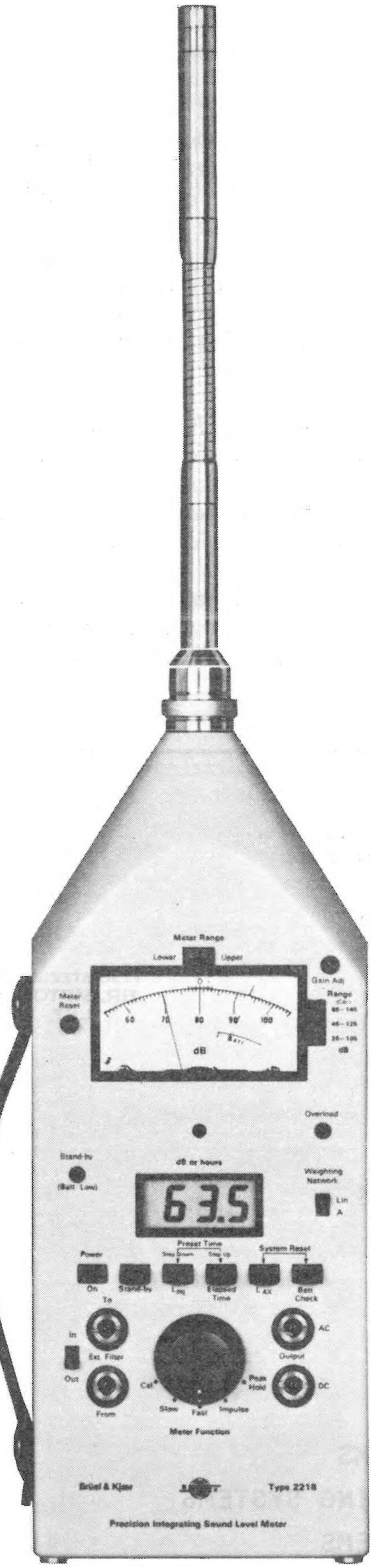

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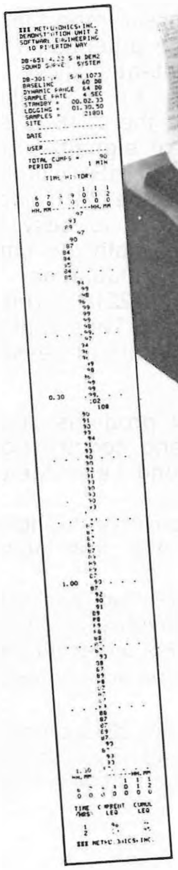

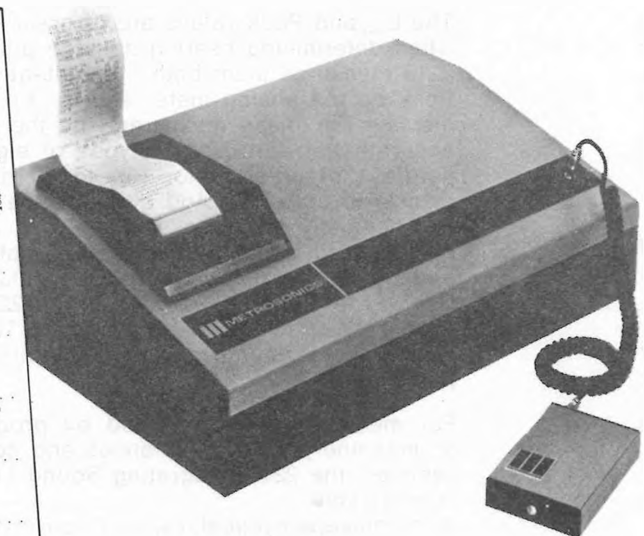

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Table 3

Effects of Background Noise (Continuous Variable) on Aggregate Response to Aircraft Noise

<u>Interaction effect</u>:

Response Variable	Incremental explained variation (R^2) due to independent variables: AC L_{eq}	Cross Product	Background L_{eq}
% highly annoyed	.1075*	$.0271^{NS}$	$.0359^{NS}$
% speech interference	.3708***	$.0050^{NS}$	$.0335^{NS}$
% complaints	$.0373^{NS}$	$.0001^{NS}$	$.0583^{NS}$

<u>Independent effect</u>:

Response Variable	R^2	Std. Error
% highly annoyed $\%HA = -100.6 + 1.733^{**}\ AC\ L_{eq_{24}} + .564^{NS}\ BACK\ L_{eq_{24}}$	.131	19.2
% speech interference $\%SI = -121.0 + 3.271^{***}\ AC\ L_{eq_{24}} - .330^{NS}\ BACK\ L_{eq_{24}}$	.378	18.1
% complaints $\%C = -33.9 + 0.853^{NS}\ AC\ L_{eq_{24}} - .028^{NS}\ BACK\ L_{eq_{24}}$	.037	18.4

NS not significant at .05 level

* significant at .05 level

** significant at .01 level

*** significant at .001 level

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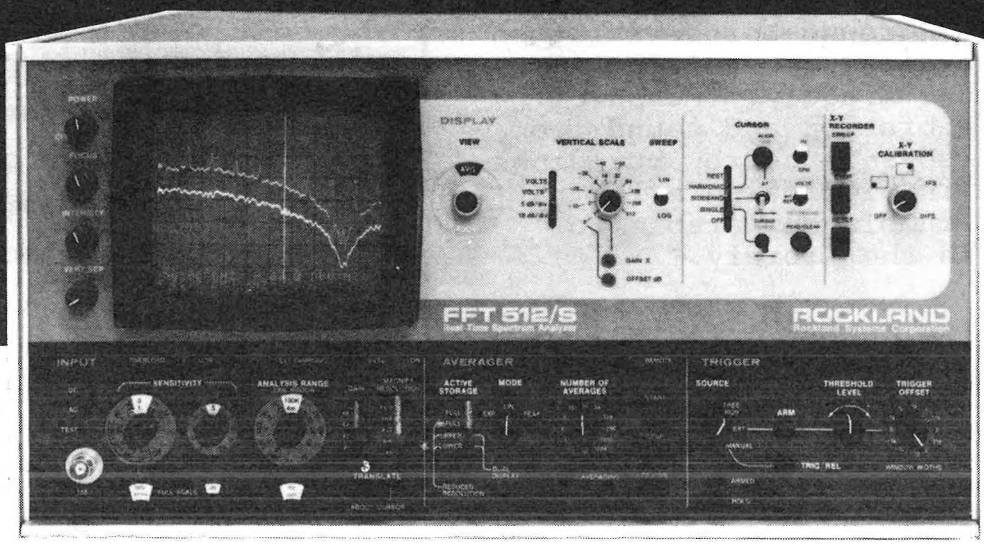

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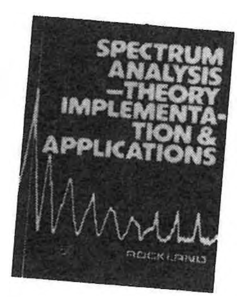

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MEASUREMENTS AND PREDICTION OF SOUND LEVELS IN QUIET URBAN AREAS - URBAN HUM

Tim Kelsall

Hatch Associates Ltd.
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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

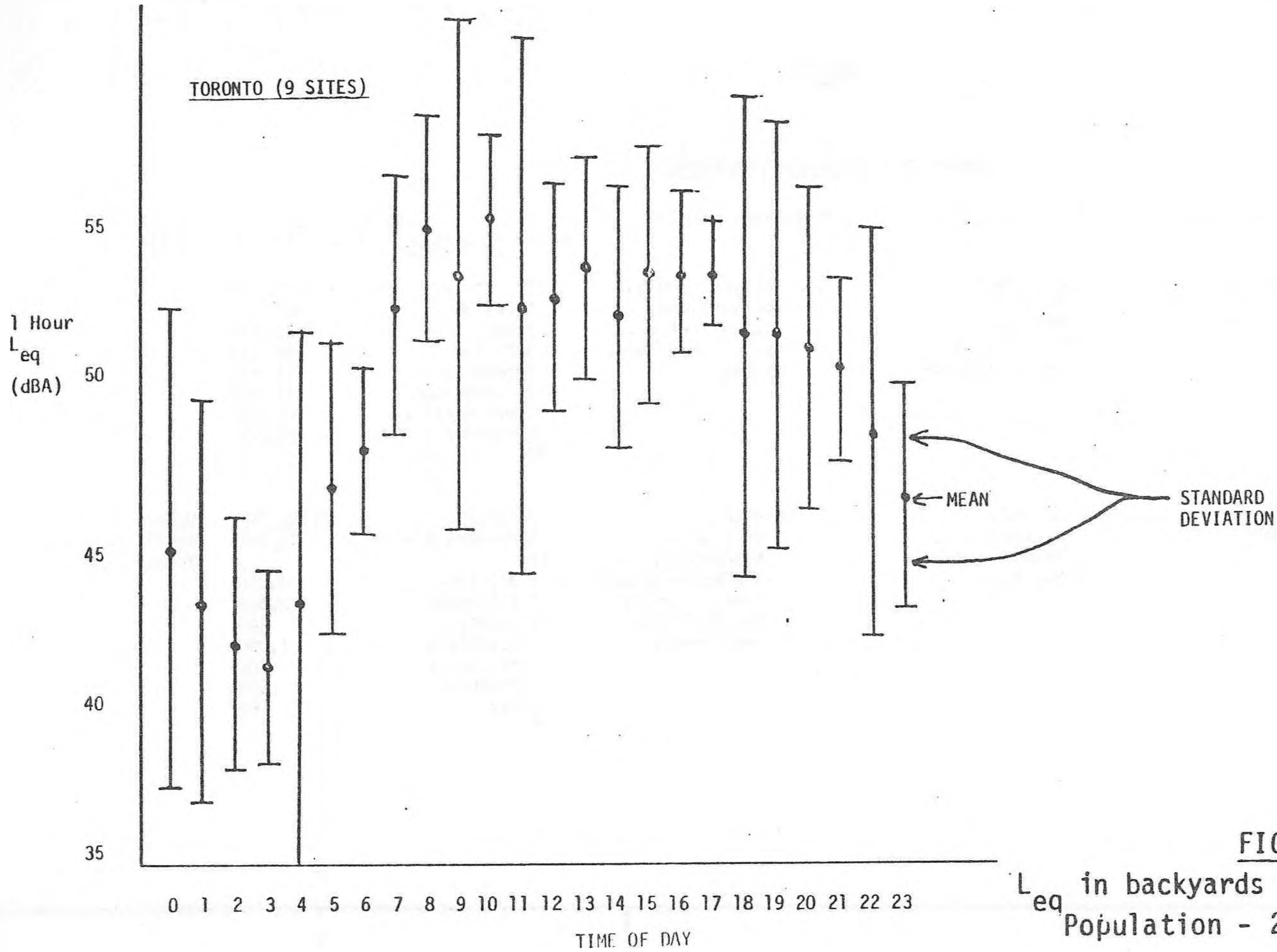

FIGURE 1 a

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

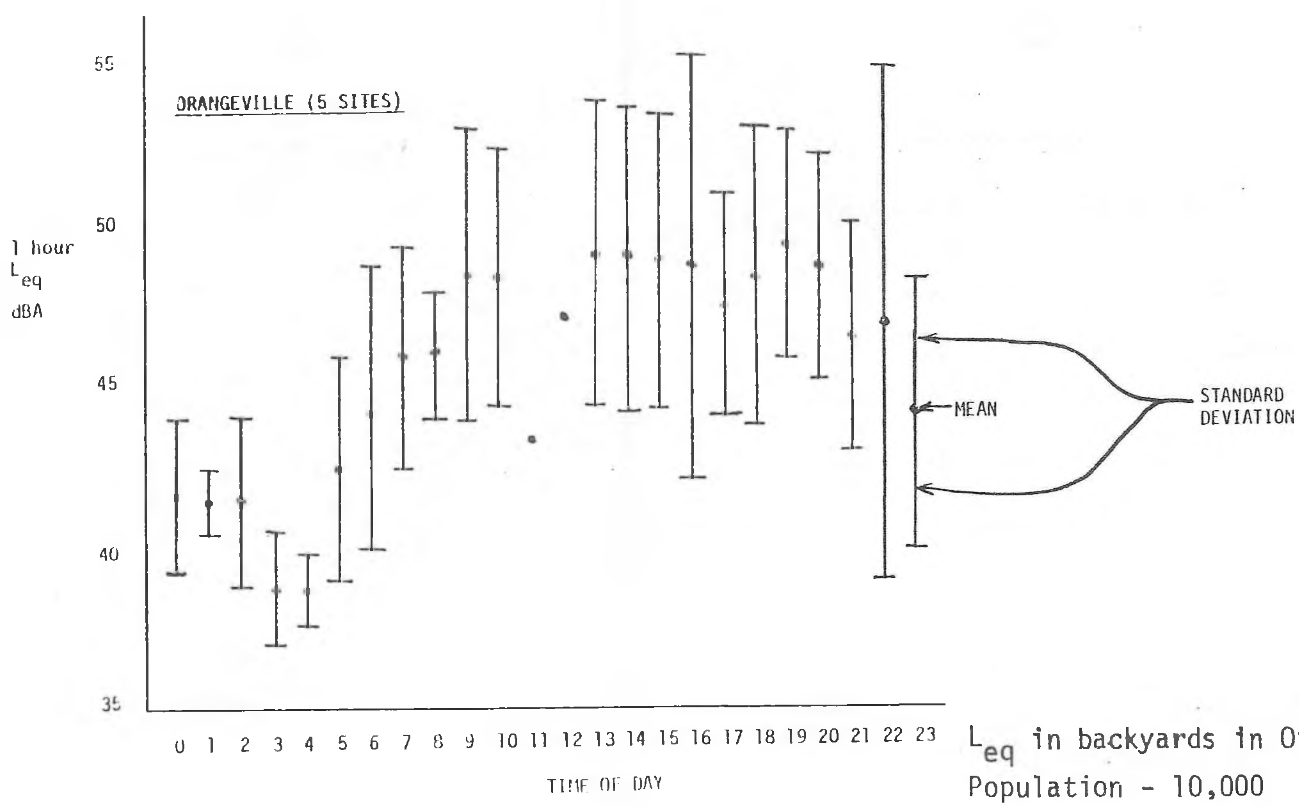

FIGURE 1 b

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

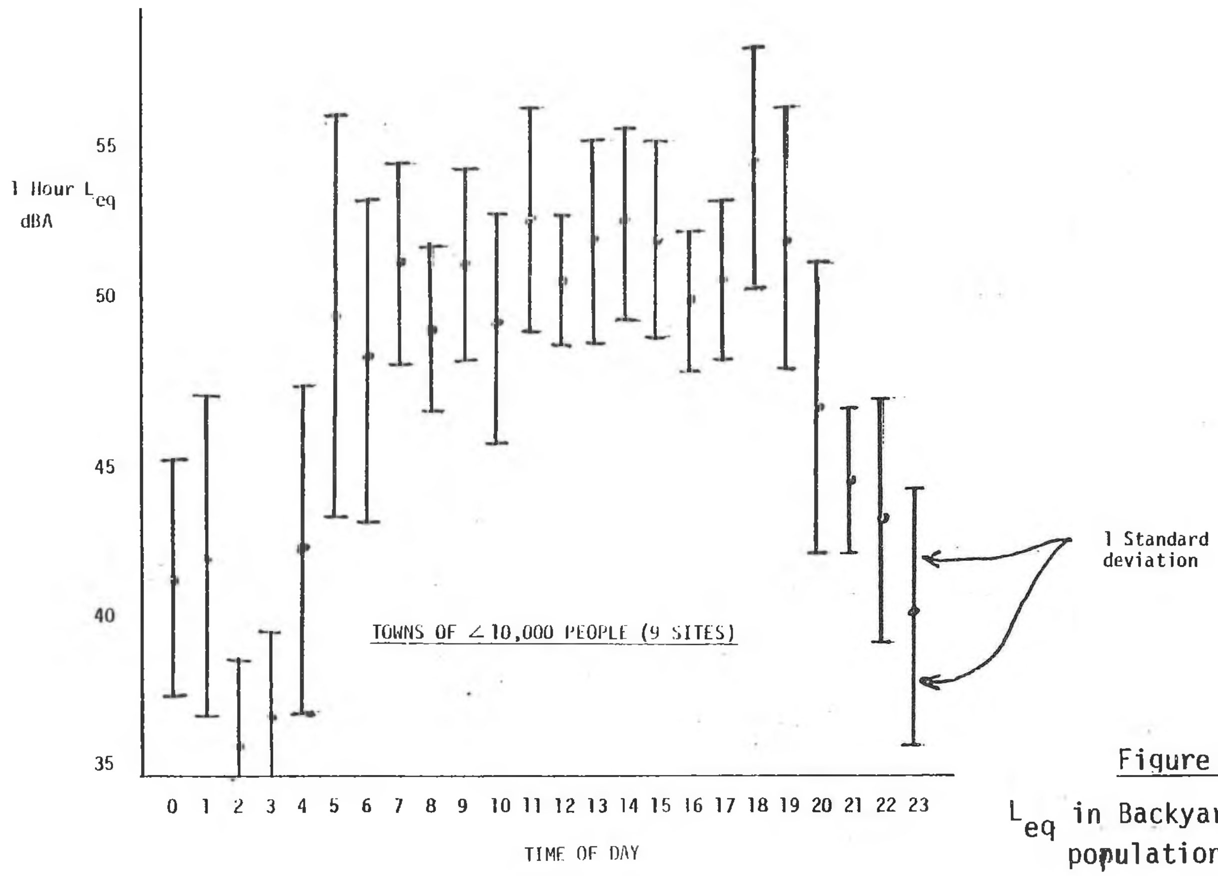

Figure 1 c

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

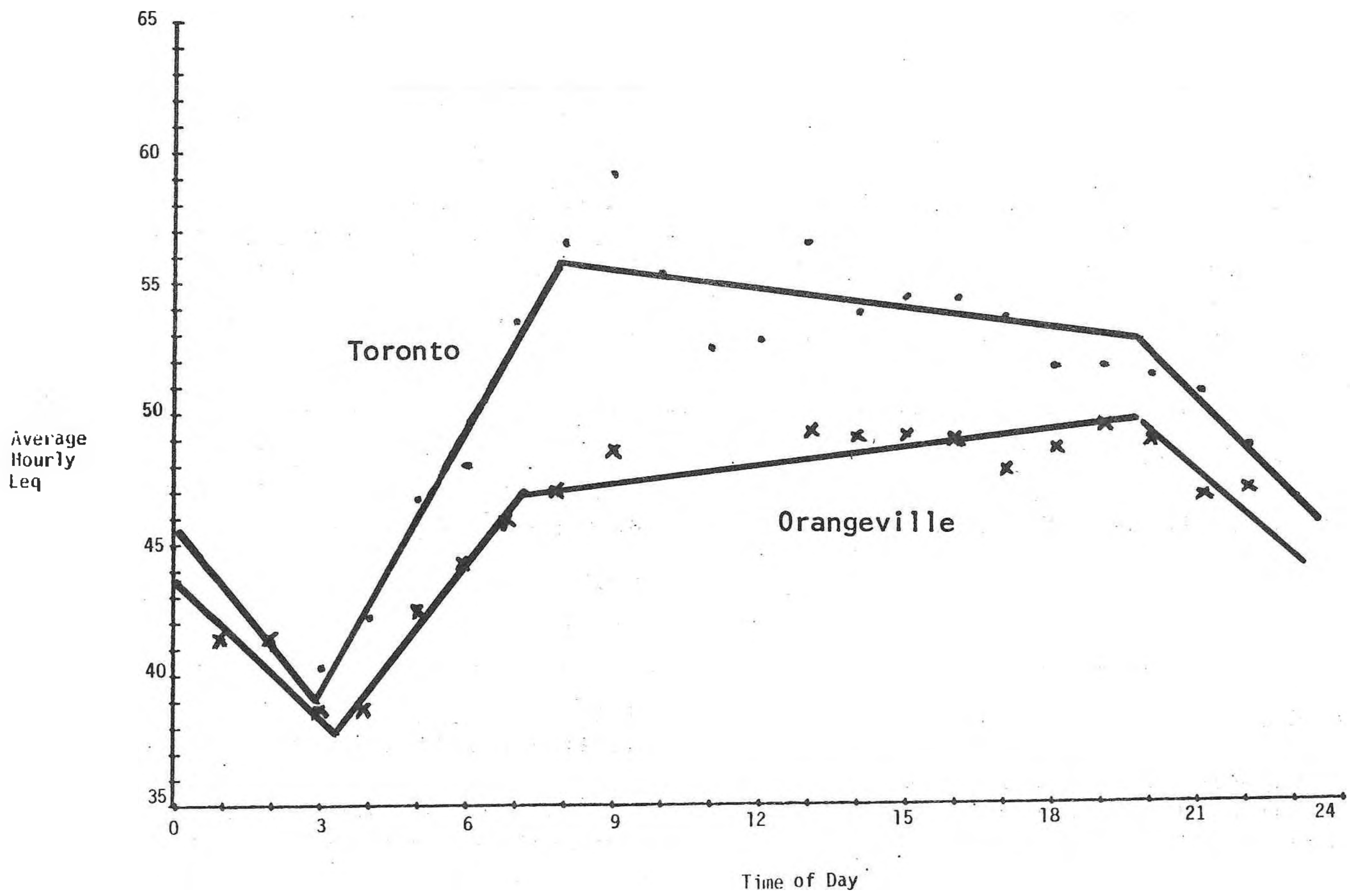

Figure 2. Straight line approximation to variation of hourly L_{eq} with time of day; (a) Toronto, (b) Orangeville

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