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ROAD TRAFFIC NOISE ANNOYANCE IN RELATION TO AVERAGE NOISE LEVEL, NUMBER OF EVENTS AND MAXIMUM NOISE LEVEL

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The extent of annoyance caused by road traffic noise was investigated in 15 areas with a varying number of vehicles and different distances between the traffic and houses. The goal was to compare two principles for expressing noise exposure. One was based on the conventional energy equivalent value in terms of a 24-hour L_{Aeq} value. The other was based on the number of events and noise level as two independent variables. A postal questionnaire study was performed in the different areas, and noise exposure measurements were made at a representative site in each area. The individual noise exposure was calculated on the basis of the distance of the respondent from the road and the floor level. The results showed that the number of noise events did not influence the extent of annoyance. There was a strong relationship between the L_{Aeq} and the extent of annoyance as well as between the maximum noise level and the extent of annoyance. These data suggest that actions to control the disturbing effects of road traffic noise should focus on noisy vehicles and that limiting the number of vehicles would not have an effect on the extent of annoyance.

1. INTRODUCTION

Noise from vehicles is one of the most important environmental pollutants affecting man's health and well being [1]. Control actions to decrease the effects of noise thus have high priority in work to decrease the effects of the environment. A prerequisite for this control to function is that the noise dose is highly related to the effect and that the control to be undertaken is easy to implement and to understand. The dose must be clearly defined, and the control measures must give priority to the factors that are most important for the effect.

Environmental noise is usually expressed as the average of all noise events over a certain time, e.g., 24 hours or as day or night values. If means are formed for the extent of annoyance in several areas with the same exposure level, there is a relatively good dose–response relationship [2].

A number of field studies on aircraft noise were undertaken in the 1960s and 1970s to evaluate the relative role of the two subcomponents, numbers of events and noise levels [3–6]. In summary, the results from these studies demonstrated that only the noise events at or above 70 dB(A) needed to be considered when estimating the risk for annoyance. An increase in the number of such events initially increased the extent of annoyance but, at a threshold number, a further increase in the number did not increase the extent of annoyance.

As regards noise levels, the closest association with the extent of annoyance was for the maximum level, defined as that occurring 3–5 times/24 hours. In areas exposed to a small number of noise events, below the threshold, the noise levels did not influence the extent of annoyance, whereas this became the major factor above the threshold [7].

As regards road traffic noise, the validity of these principles has not been assayed in detail. A similar type of relationship has been reported where the number of events was expressed as the number of heavy vehicles and the noise level as the average of the three highest noise levels during a one-hour measuring period [8, 9]. The evidence presented is not sufficient, however, as noise levels of 70 dB(A) or above are not emitted exclusively by the heavy vehicles.

To further investigate annoyance caused by road traffic noise, a field study was performed in collaboration between a Japanese and a Swedish research group. The goal of the investigation for the Japanese group was to evaluate possible differences in the extent of annoyance that were related to housing conditions (flats, semidetached houses, and villas) [10]. The goal of the Swedish group was to investigate the relation between the extent of annoyance and different noise exposure indices. This manuscript describes the findings from the Swedish investigation. The study is a collaboration resulting from the series of Japanese–Swedish noise symposia that have been held over the last 10 years [11–13].

2. MATERIAL AND METHODS

2.1. AREAS INVESTIGATED

The areas were chosen to include as large as possible a variation in the two basic parameters number of vehicles and distance from road (= variation in noise levels). A large number of potential areas in West Sweden were visited, and 15 areas were selected for the study.

2.2. POPULATION

A random sample of 60–178 persons, aged 18–75 years and having lived in the area for at least one year was chosen from each of the investigated areas using population registers. The selected persons received an information letter and a questionnaire similar to the one used in previous studies [4, 6, 10, 11]. It contained about 40 questions on general sources of annoyance in the area, questions on family status, occupation, general satisfaction with the environment and specific questions on annoyance caused by different environmental noise sources. The respondent was asked whether she/he noticed a particular noise source and, if so, if they were annoyed (a little annoyed, rather annoyed, very annoyed). A reminder letter was sent if they had not answered within a fortnight, and an additional reminder, this time with another copy of the questionnaire, after another fortnight.

2.3. NOISE MEASUREMENTS

The traffic noise flow and the noise exposure was measured at a reference point in each area. This point was located at a representative position in the middle of the area approximately 5 m from the road edge. The traffic was counted manually during a 24-hour weekday or in parallel with the noise measurements. The observers also noted extreme noise events such as broken noise mufflers and squeaky braking. These events were later coupled to the registration of maximum noise levels and were excluded.

A mobile laboratory was placed on the site, and a microphone (Brüel & Kjær 4184) was placed 1·5 m above the ground. This was connected to a noise level analyzer (Brüel & Kjær 4435). The measurements were made continuously for 24 hours during a weekday. Maximum noise levels were registered continuously, and the 24-hour L_{Aeq} was calculated.

For each person in the study, the noise level was corrected from the value for the area, taking into consideration the distance to the road and the level of the floor above the ground. The correction was based on field measurements where road traffic noise was measured at 5, 10, 20 and 40 m from the source and in an open ground. Based on these results, distance reduction equations were calculated and applied in each area.

The maximum noise level was defined as the level which was exceeded at least three times/24 hours. It represents a maximum value that is reached regularly in the area. A single, very high noise would thus not be of importance.

2.4. TREATMENT OF DATA

Earlier investigations have shown that the extent of annoyance is dependent on the layout of the flat or house [14]. Among those living in dwellings with windows facing only a street with traffic, the extent of annoyance is about 15% larger as compared to that for flats with windows also facing a quiet side of the house. In this material, the number of dwellings with windows facing only to the road with noise was small (n = 132, 9·2%), and these were excluded from the material.

For each area, the percentage of respondents who indicated that they were very annoyed by the traffic noise was calculated. When the individual noise exposures had been calculated, the respondents were grouped into noise exposure categories with 5 dB intervals. These categories did not correspond to the original areas, as the variation in individual noise level within an area could be larger than differences between different categories. The average annoyance within each category was calculated from numerical values for the annoyance (very annoyed = 5, rather annoyed = 4, a little annoyed = 3, notice noise but not annoyed = 2, does not notice = 1), and an average annoyance for each noise exposure category was calculated.

The relationships between different noise indices and annoyance were calculated by using regression analysis. The data from the noise measurements and the extent of annoyance in different areas are reported in the Appendix.

3. RESULTS

3.1. AREA EXPOSURE

Figure 1 shows the relationship between the noise level expressed as the area L_{Aeq} and the extent of annoyance in the different areas. The figure shows that there was a fair relationship (r_{xy} = 0·5769).

Figure 2 shows the relationship between the extent of annoyance and the number of vehicles. There was a fair relationship (r_{xy} = 0·5381). The relationship was about the same for the number of noise events exceeding 75 dB(A) per 24 hours (r_{xy} = 0·5199).

Figure 3 shows the relationship between the extent of annoyance and the noise exposure expressed as heavy vehicles. There was a fair relationship (r_{xy} = 0·8163), but the slope of the dose–response curve was determined by one area only (area Alingsås 2).

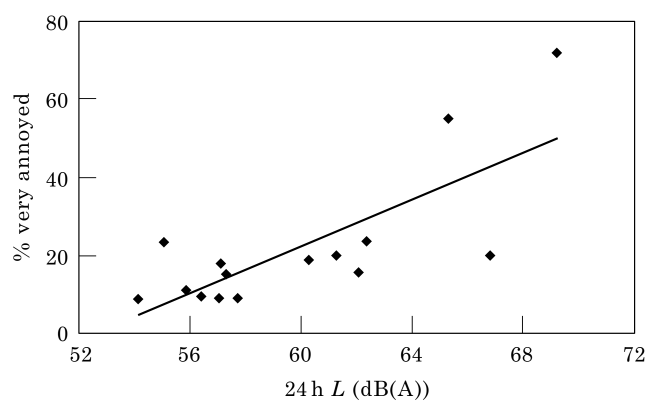

Figure 1. The relation between extent of annoyance in different areas and the area noise exposure expressed as L_{Aeq}.

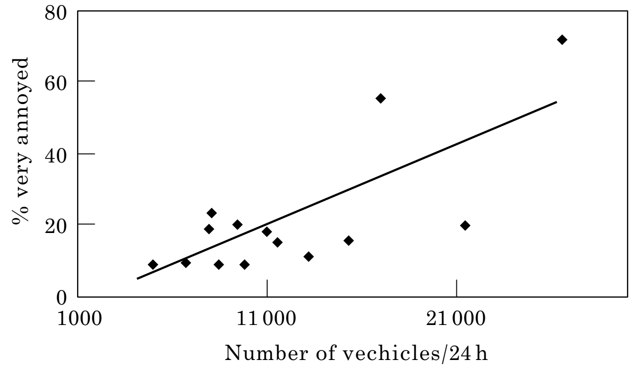

Figure 2. The relation between the extent of annoyance and the area noise exposure expressed as the number of vehicles.

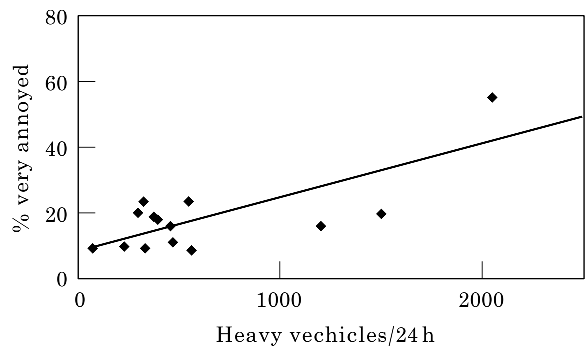

Figure 3. The relation between extent of annoyance in different areas and the number of heavy vehicles.

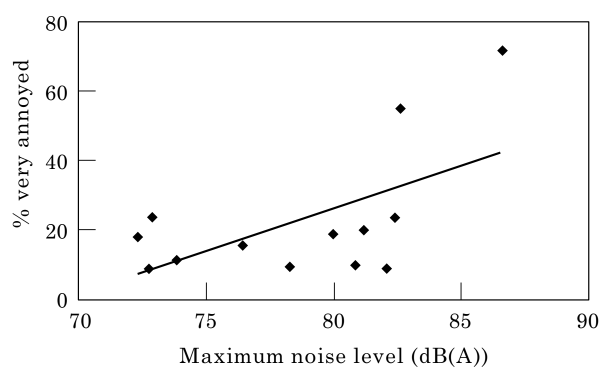

Figure 4. The relation between extent of annoyance in different areas and the max dB(A) values.

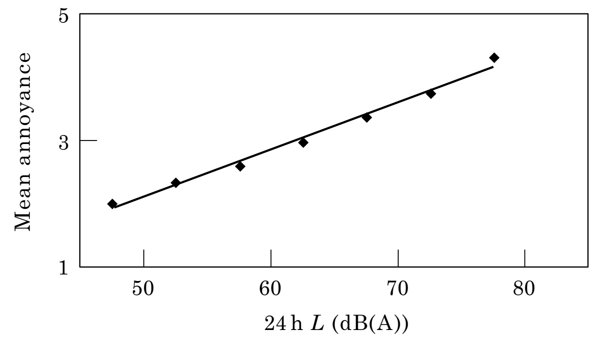

Figure 5. The relation between average annoyance and personal noise exposure expressed as L_{Aeq} in 5 dB classes.

Figure 4 shows the relation between the extent of annoyance and max dBA values. Annoyance and max dB(A) values were poorly correlated (r_{xy} = 0·3382).

3.2. INDIVIDUAL NOISE EXPOSURE

Figure 5 demonstrates the relationship between the noise exposure, expressed as individual L_{Aeq}, and the average annoyance in different classes of noise exposure. The figure shows that there was a strong relationship (r_{xy} = 0·9886).

Figure 6 shows the relationship between the average annoyance and the noise exposure expressed as number of vehicles in excess of 75 dB(A) in different classes. The figure shows that the number of events above 75 dB(A) was not related to the extent of annoyance.

Figure 7 shows the relationship between the average annoyance and the noise exposure expressed as maximal noise level. The figure shows that there was a strong relationship (r_{xy} = 0·9713).

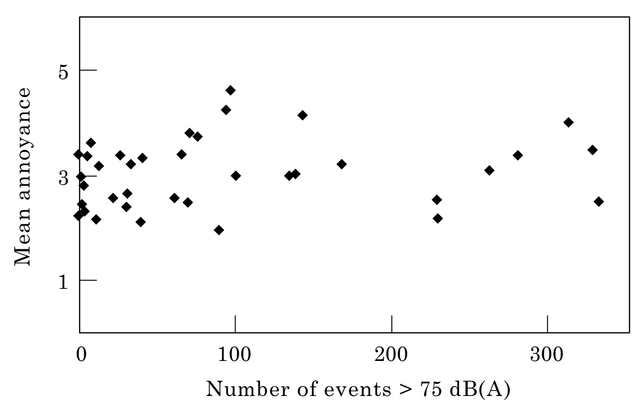

Figure 6. The relationship between the average annoyance and personal noise exposure expressed as number of vehicles in excess of 75 dB(A).

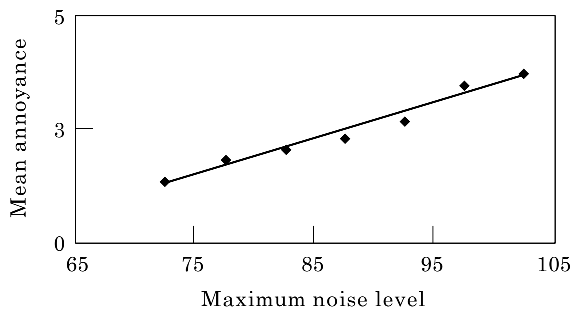

Figure 7. Relationship between average annoyance and personal noise exposure expressed as maximum noise level in 5 dB(A) classes.

4. COMMENTS

Investigations like the one reported here have several potential shortcomings from a methodological point of view. The noise measurements were made only at one time, and it is difficult to assess how representative they were. On the other hand, experience from previous studies shows that the road traffic patterns are quite stable during weekdays and that the noise levels are about the same. The short measurement time would thus not influence the results. Also, the conclusions drawn by comparing different noise indices were all based on the same measurement periods.

Other methodological difficulties are related to the questionnaire technique. Although the response rate was similar to those in previous investigations [4, 7, 8], the possibility that there is a response bias in the drop-out cannot be ignored. Earlier analysis of the drop-out in environmental noise studies have, however, shown that the drop-out selection leads to a slight overestimation of the extent of annoyance, the drop-out being present mainly among those who are not annoyed (Åhrlin, unpublished). Other errors that could influence the results are media publicity on the noise source and different public actions against the noise source, which can lead to an increased reporting of annoyance. No such activities were present in the areas investigated. Again, as the purpose of the study was to compare two different noise indices, such errors would not influence the conclusions.

This investigation calculated the individual noise dose, correcting for distance to the road and floor level. Earlier investigations have determined the noise exposure as an area value, measured in a representative spot. This technique is probably adequate for aircraft noise which exposes the area in a relatively uniform pattern. Road traffic noise, on the other hand, is more variable within an area. Measurements have been made at the persons' homes in some investigations, but this was too cumbersome to undertake in this study. After the correction for individual values, the area could no longer be used as the basis for calculating group averages. The differences within an area for the correction applied varied between 3 and 11 dB, which is in the same order as the differences between different areas.

The relationships between noise exposure calculated as individual exposures and annoyance demonstrated some important features. The relationship for L_{Aeq} was very strong as was the relationship for L_{max}. There were, however, only weak relationships between annoyance and the number of vehicles or the number of vehicles with a noise level in excess of 75 dB(A). From a human perception point of view, this is reasonable as it becomes increasingly difficult to distinguish between two exposure situations with different numbers of events as the latter increases and the noise is instead perceived as a continuum. This finding also agrees with previous results from studies on aircraft noise at larger airports [3]. On the other hand, at smaller airports, the number of events becomes more important than the noise level [7].

With regard to actions to reduce the extent of annoyance in the population, these can theoretically comprise measures to reduce the number of vehicles or the noise levels. Both actions would decrease the L_{Aeq} value, although reducing the noise level would be more efficient (-3 dB $= \frac{1}{2}N$). The results from this study demonstrate that a reduction in the number of vehicles will not reduce the extent of annoyance around streets with a traffic pattern similar to the ones studied here. The relevant action is instead to decrease the maximum noise level by prohibiting the noisiest vehicles. It has previously been shown that these comprise only a few percent of the total number of vehicles in city traffic [15]. Actions to decrease the number of noisy vehicles would thus not be very drastic in relation to the overall traffic pattern. Additional studies need to be undertaken to support this hypothesis.

A previous suggestion has been to issue noise certification for streets [16]. This implies that every street is given a certain maximum noise level limit, calculated according to the noise value at the facade and a given extent of annoyance that can be accepted. Vehicles would need to be noise certified and if they were to emit noise in excess of the stated value, they would not be allowed to use the street. With this system, control of individual vehicles is easy to achieve. This approach would also turn the responsibility for noise abatement activities to the manufacturer of the vehicles and to the driver, thus reducing the annoyance caused by road traffic noise.

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APPENDIX

TABLE A1

Number of respondents, response rate and extent of annoyance in different areas

Area	Sample	Response rate (%)	Rather + very (%)	Very annoyed (%)
Gothenburg				
1.	101	55·4	93	72
2.	71	70·4	58	23·4
3.	72	63·9	35	9·1
4.	106	76·4	54	23·4
5.	87	74·7	38	20
6.	86	73·3	17	8·9
7.	178	74·7	19	9·2
Borås				
1.	171	63·2	37	15·8
2.	135	68·1	43	20
3.	154	73·4	43	19
Alingsås				
1.	292	71·6	28	15·5
2.	108	76·9	73	55
3.	147	72·1	28	18·1
Kungälv				
1.	104	73·1	20	11·3
2.	60	58·3	14	9·7
Total	1872	70·3	–	–

TABLE A2

Noise exposure in different areas

Area	No. vehicles	No. vehicles >75	L_{Aeq}	dB_{max}
Gothenburg				
1.	26 533	786	72	96
2.	8090	177	67	102
3.	5025	65	63	92
4.	8117	2	64	91
5.	9461	87	66	93
6.	8418	3	65	86
7.	9847	16	67	89
Borås				
1.	15 236	45	67	89
2.	21 497	145	73	99
3.	7935	0	63	84
Alingsås				
1.	11 545	26	68	97
2.	17 062	177	70	94
3.	10 960	6	63	87
Kungälv				
1.	13 223	6	67	93
2.	6740	207	68	97