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EFFECTS OF EXPOSURE TO RAILWAY NOISE—A COMPARISON BETWEEN AREAS WITH AND WITHOUT VIBRATION

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This paper presents some of the results of field investigations on effects of exposure to noise and vibration from railway traffic. Effects on annoyance, sleep disturbances and psycho-social well-being as well as disturbance of different activities were evaluated by a postal questionnaire. Fifteen different sites located near railway lines in Sweden were investigated. The study covered areas with different number of trains per 24 hours in areas with strong vibration caused by the railway traffic exceeding 2 mm/s as measured in the buildings as well as areas without vibration, or vibration weaker than 1 mm/s. 2833 persons between 18 and 75 years of age participated in the study. This paper presents only the results from two areas with and without vibration and a high number of trains per 24 hours. The results show that railway noise is experienced as more annoying in areas where there is simultaneous exposure to vibration from railway traffic. Disturbance of communication was the most frequently mentioned annoyance reaction, outside and inside the dwelling. To ensure an acceptable environmental quality where less than 5% of the exposed population is rather or very annoyed by railway noise, these noise levels must be below 80 L_{Amax} and below 55 L_{Aeq} in areas without vibration. In areas with simultaneous exposure to strong vibration, action against vibration or a longer distance between houses and the railway line is needed, corresponding to a 10 dB(A) lower noise level than in areas without vibration.

1. BACKGROUND AND AIM

A majority of the studies reported in the literature show that railway noise causes less general annoyance (4–15 dB) than road traffic noise [1]. In Sweden, railway noise is a minor problem as compared to road traffic noise [2, 3]. About 350 000 people are exposed to noise levels from railway traffic exceeding 55 dB(A) L_{Aeq}, whereas about 1 600 000 people are exposed to similar noise levels from road traffic. For road traffic, the recommended guideline value for dwellings is 55 dB(A) L_{Aeq} (outside level). For indoor levels, 30 dB(A) L_{Aeq} per 24 hours and 45 L_{Amax} during night time are recommended. There are at present no guideline values for railway noise in Sweden but, as new railway lines are planned and railway traffic is increasing, there is an urgent need for guideline values.

A study involving a number of investigations in different areas with and without vibration was designed to elucidate different effects of noise and vibration from railway traffic as a basis for Swedish guideline values.

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2. METHOD AND MATERIALS

2.1. DESIGN OF THE STUDY

In the first phase, and as a basis for the design of the study, an inventory of the Swedish railway lines was performed. Parameters of interest were the extent of vibration in buildings caused by railway traffic, total number of trains per 24 hours and proportion of freight trains. The following parameters were included in the design of the study: vibration level (<1 mm/s, >2 mm/s) and number of trains (less than 25 trains to over 150 trains per 24 hours). In a second phase, all cities and suburbs located near railway lines with low, medium or high number of trains per 24 hours and having more than 1000 inhabitants were identified in areas with and without vibration. In a third phase, before the final selection of areas, site visits were made at each area. In total, 15 cities or urban areas were selected for the investigation. The sites were located between ten and about 300 m from the railway line.

2.1.1. *Noise exposure*

Noise levels were calculated according to the Nordic calculation model for railway noise. The levels were calculated in 5 dB(A) intervals for L_{Amax} and L_{Aeq}. In some of the areas, control measurements were made at different distances from the railway line.

2.1.2. *Vibration*

The aim was *not* to study vibration in detail, but vibration levels in the buildings had previously been measured in some of the areas classified as areas with strong vibration. Vibration level is expressed in mm/s [mean maximum level not frequency weighted]. The vibration level varies with type of house, distance from the railway line and with speed and weight of the trains. The distance between each house and the railway line was therefore measured on the map and questions about the construction of the dwelling were included in the questionnaire.

Table 1 shows the design of the study and the noise levels in areas with and without vibration. Most categories of area include at least three different sites. Each category of area is named after the first (underlined) site: Huskvarna, Hässleholm and Lund (without vibration) and Säffle, Kungsbacka and Partille (with vibration). The number of freight trains is written in brackets. Only results from the two areas Lund and Partille are presented in the following.

TABLE 1

Design, sites and noise exposure

	<25 trains/24 h	25–75 trains/24 h	76–100 trains/24 h	>100 trains/24 h
		Vibration <1 mm/s		
Site		Huskvarna Tenhult, Forserum	Hässleholm Sösdala, Höör	Lund, Stångby Örtofta, Eslöv
Number		48 [19]	85 [39]	143 [44]
L_{Amax}		70–95	70–95	65–95
L_{Aeq}		40–70	45–70	40–70
		Vibration >2 mm/s		
Sites	Säffle, Grums Vålberg	Kungsbacka		Partille
Number	20 [9]	59 [25]		160 [53]
L_{max}	70–90	70–95		70–95
L_{Aeq}	40–65	45–65		45–75

2.1.3. *Evaluation of effects*

The effects were evaluated by a postal questionnaire similar to the one previously used in studies on road traffic noise. The questionnaires were sent together with an introductory letter to one person in each household between 18 and 75 years of age who had lived in the area for at least one year. The main questionnaire was designed in such a way as to conceal the real object of the enquiry. It contained questions about the dwelling and the neighbourhood, annoyance related to different sources in the neighbourhood (noise, dust, exhausts, vibration etc.), work environment, sleep and sleep disturbances and questions on health and general well-being. General annoyance was evaluated by a five-point verbal category scale: 0 = "do not observe", 1 = "observe, but is not annoyed", 2 = "not very annoyed", 3 = "rather annoyed" and 4 = "very annoyed". The questionnaire also contained questions on different parameters that are known to act as modifiers of annoyance such as noise sensitivity, position of bedroom windows and construction of the house.

Those who responded that they were "rather" or "very" annoyed by noise or vibration from railway traffic received a second questionnaire with specific questions on disturbance of different activities.

3. RESULTS

The results from the two areas with the highest number of trains, Partille with vibration and Lund without vibration, are presented here. The response rate for the main questionnaire in the two areas was 72 and 77%, respectively, or 390 (Partille) and 553 (Lund) respondents. The response rate for the second questionnaire on activity disturbances was 90% in both areas.

Socio-demographic factors such as age, time of residence, employment rate, noise sensitivity and general health were similar in the two areas. A majority of respondents lived in villas or terraced houses. Most respondents were very satisfied with their dwelling and their neighbourhood, and perceived environmental quality was high in both areas.

3.1. GENERAL ANNOYANCE TO RAILWAY NOISE

Table 2 illustrates annoyance to railway noise at different L_{Amax} levels. It shows that, at similar noise levels, the average mean annoyance reaction as well as the percentage of rather + very annoyed respondents was much higher in the area with strong vibration (e.g., 22% higher at levels between 81 and 85 L_{Amax}) and 29% higher at levels between 66 and 70 L_{Aeq} (see Table 3).

TABLE 2

Annoyance to railway noise at different L_{Amax} levels

	70–75 L_{Amax} Annoyance		76–80 L_{Amax} Annoyance		81–85 L_{Amax} Annoyance		86–90 L_{Amax} Annoyance		91–95 L_{Amax} Annoyance	
L_{Amax}	Mean	rather + very	Mean	rather + very	Mean	rather + very	Mean	rather + very	Mean	rather + very
Partille (vibration)	1·10	8·1	1·35	10·7	1·77	29·6	2·58	53·3	2·88	60·6
Lund (no vibration)	0·83	0	1·01	2·7	1·23	7·2	1·71	18·0	2·03	34·3

TABLE 3

Annoyance to railway noise at different L_{Aeq} levels

L_{Aeq}	46–50 L_{Aeq} Annoyance Mean	46–50 L_{Aeq} Annoyance rather + very	51–55 L_{Aeq} Annoyance Mean	51–55 L_{Aeq} Annoyance rather + very	56–60 L_{Aeq} Annoyance Mean	56–60 L_{Aeq} Annoyance rather + very	61–65 L_{Aeq} Annoyance Mean	61–65 L_{Aeq} Annoyance rather + very	66–70 L_{Aeq} Annoyance Mean	66–70 L_{Aeq} Annoyance rather + very
Partille (vibration)	0·93	0	1·26	12·4	1·26	9·6	1·99	34·7	2·71	61·3
Lund (no vibration)	0·81	0	1·03	3·2	1·18	6·7	1·80	19·1	1·94	32·3

The mean average annoyance reaction was better correlated with the different noise measures than the percentage of rather + very annoyed or the percentage of very annoyed respondents. (Vibration area: L_{Amax}, 0·98, 0·97 and 0·93, respectively, and L_{Aeq}, 0·97, 0·96 and 0·91, respectively. Areas without vibration: L_{Amax}, 0·99, 0·91 and 0·88, respectively, and L_{Aeq}, 0·98, 0·92 and 0·88, respectively.)

3.1.1. *Comparisons between annoyance to nosie and vibration*

Figure 1 shows comparisons between annoyance to noise and vibration respectively at different distances from the railway line. The figure shows that the average annoyance reaction was higher for vibration than for noise up to about 200 m from the railway line.

The location of the bedroom has a significant effect $p < 0.001$ on general annoyance. This is shown in Table 4. The table shows that respondents who lived in apartments with bedroom windows facing the railway line were more annoyed by noise than those having bedroom windows not facing the railway. About 40% of those who were exposed to outside noise levels about 80 L_{Amax} and had bedroom windows facing the railway seldom or never slept with open windows as opposed to 20% among in the group with windows *not* facing the railway.

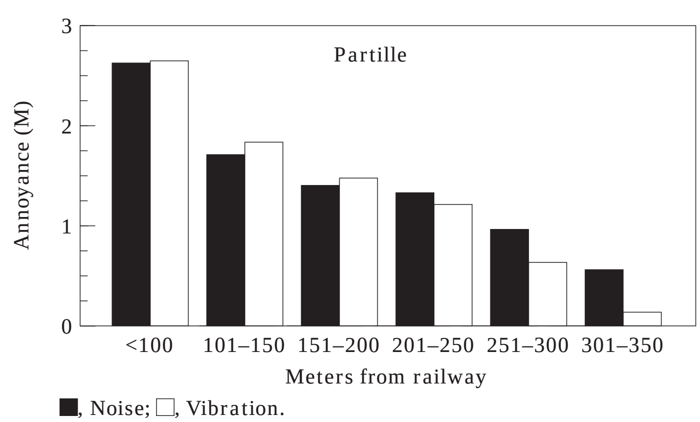

Figure 1. Annoyance to noise and vibration at different distances from the railway line. ■, Noise; □, Vibration.

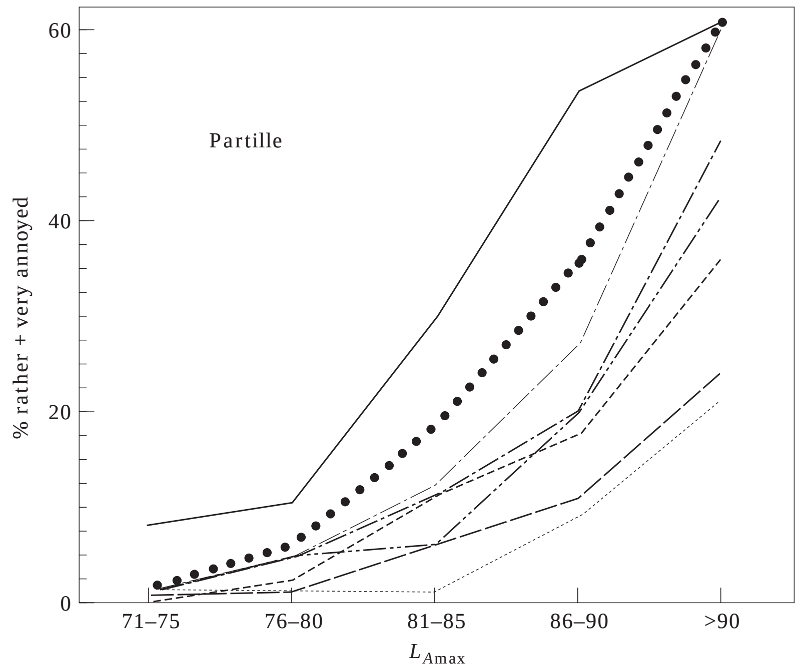

Figure 2. Percentage of respondents who reported that they were rather or very annoyed by railway traffic during different activities in areas without vibration. ——, annoyance; ● ● ●, outdoor speech; — – —, radio/tv; ▬ ▬ ▬, outdoor relaxation; — - - —, indoor relaxation; – – –, indoor speech; — — —, awakenings; ...., fall sleep.

3.2. ACTIVITY DISTURBANCE

Disturbance of different activities was evaluated by the second questionnaire sent to respondents who had reported in the main questionnaire that they were rather or very annoyed by noise or vibration from railway traffic. The results showed that 98% in the vibration area and 89% in the area without vibration were annoyed by railway traffic every day or at sometime during the week. About half of the respondents were more annoyed during specific times of the year, mostly during summer. Annoyance reactions were also more frequent during evenings and night-time.

The response pattern of general annoyance and activity disturbances outdoors and indoors due to noise and vibration from railway traffic is shown in Figure 2 for the area with vibration. The result is calculated as percentage of the total number of respondents on the main questionnaire. The figure shows that disturbance during communication

TABLE 4

Annoyance to noise in relation to outdoor noise level and location of bedroom windows

	Partille (Vibration >2 mm/s) Annoyance (mean value)				Lund (vibration <1 mm/s) Annoyance (mean value)			
	n	Facing railway	n	Not facing railway	n	Facing railway	n	Not facing railway
$>80\ L_{Amax}$	28	3·0	131	2·06	84	1·89	168	1·29
$<80\ L_{Amax}$	24	2·0	207	1·10	23	1·30	276	0·84

outdoors was mentioned frequently, followed by radio/TV, relaxation outdoors and relaxation indoors. Sleep disturbance effects were less frequently mentioned. There was a strong increase in disturbance at noise levels higher than 81–85 L_{Amax}. This was also the case in areas without vibration.

4. CONCLUSIONS

The results on general annoyance and activity disturbances in this study show that railway noise is experienced as more annoying in areas where there is simultaneous exposure to vibration from trains. This may be caused by difficulties the individual has in differentiating between noise and vibration, which leads to exacerbation of annoyance from noise. Vibration may also make habituation to noise more difficult. In the area with vibration >2 mm/s, vibration was generally experienced as at least as annoying as noise up to about 200 m from the railway line.

To ensure an acceptable environmental quality where less than 5% of the exposed population is rather or very annoyed by railway noise, these noise levels must be below 80 L_{Amax} and below 55 L_{Aeq} dB(A), respectively, in areas without vibration. In areas with simultaneous exposure to strong vibration, action against vibration or a longer distance between houses and railway line is needed, corresponding to a 10 dB(A) lower noise level than in areas without vibration.

The results indicate that annoyance from noise from railways can be prevented/reduced if bedrooms are located in the quieter side of the house.

Interference with speech and communication is the dominating reaction to railway traffic. It is thus important to take measures against these effects especially for dwellings and schools.

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