Adverse health effects before and after reduction in road traffic

E. Öhrström

Department of Environmental Medicine, Göteborg University Box 414, SE-403 50 Göteborg, Sweden

The paper presents results from new field studies on the prevalence of adverse health effects before and one year after a substantial (90 %) reduction of road traffic. Previously performed studies in the same residential area in 1986 and 1987 before and after traffic regulations at night indicated that road traffic noise not only causes adverse effects on sleep quality but may also cause more long term effects on psycho-physiological health and well-being. These previous studies also showed that prohibition of heavy vehicles during night was not sufficient to reduce adverse effects on sleep and general well being. The new before study was performed in 1997 and the after study in 1999. The aim was to assess the adverse effects on people of long term exposure to road traffic in terms of, annoyance, activity disturbances, sleep quality and psycho-social well-being, as well as how people living in the area were affected by the changed traffic situation. The new study involved 142 individuals between 18 and 75 years of age, living between 25 and 450 metres from the heavily trafficked road. The main results were: a substantial reduction in noise annoyance, changed behaviours, increased sleep quality and reduced prevalence of psychological and physiological symptoms.

INTRODUCTION

Environmental noise causes various adverse effects. The evidence is strongest for annoyance and acute sleep disturbances [1]. Concerning long term health effects, e.g. noise-induced sleep disturbances and psycho-social well-being and psychological and physiological symptoms, the evidence is weaker and more research, preferably longitudinal studies, are required.

BACKGROUND AND AIM

The present study was performed in a heavily noise polluted city area in Göteborg, Sweden. To improve the living environment and facilitate road transport, very extensive changes were made in the road system and a new tunnel, the Lundby Tunnel, was opened for traffic in January 1998. A new longitudinal study was performed before and after the opening of the tunnel. The first part of this new study was presented in 1998 [2] and some results from the after study were presented in 2000 [3].

The aim of the study was to elucidate the effects of road traffic noise and the effect of the changes in noise exposure on annoyance, various activity disturbances, sleep quality and psychological and physiological well-being.

METHOD AND MATERIALS

The first part of the socio-acoustic survey was performed in 1997 before the opening of the new tunnel for road traffic. The tunnel was opened in January 1998 and the final part of the investigation was executed in 1999. The effects on the population were evaluated by a main questionnaire that was delivered to one or two individuals in each household between 18 and 75 years of age. The questionnaire was similar to those previously used [4] and contained questions about the dwelling, annoyance to different sources in the neighbourhood, sleep and sleep disturbances, and health and psycho-social symptoms and well-being. In the follow up study, specific questions on the various effects were added where the respondents compared the situation before and after the changes in road traffic.

The total number of respondents in 1997 was 142 (exposed area; 50 and control area; 92) and the response rate was 62 % for the main questionnaire. Of these respondents, 120 persons (exposed area; 45 and control area; 75) took part in the follow up study in 1999.
Outdoor \( L_{Aeq} \)-levels were calculated for both sides of each house based on traffic statistics obtained from the local traffic office. Indoor \( L_{Aeq} \)-levels were calculated for living-rooms and bedrooms based on measurements and calculations of noise reduction of the façade.

**RESULTS**

**Noise exposure**

The road traffic was substantially reduced when the new tunnel was built, from circa 25,000 to 2,400 vehicles per 24 hours resulting in a decrease in \( L_{Aeq} \)-levels of 9-14 dBA in the exposed area. At the noisiest façade, noise levels decreased from 56–69 to 44-57 \( L_{Aeq} \). In the control area a small reduction of 0 – 4 dB was seen.

**Annoyance, sleep and psychophysiological well-being**

The proportion of very annoyed individuals (4-graded verbal scale) fell significantly (\( p < 0.001 \)) from 58 to 7%. The size of this extent of annoyance agrees well with expected disturbance at \( L_{Aeq,24h} \geq 55 \) dB. Annoyance measured by a numeric scale 0-10 decreased from 8.9 to 1.4 mean value (\( p < 0.001 \)) in the exposed area and from 2.3 to 1.7 in the control area (\( p < 0.01 \)).

Rest, relaxation and sleep were the indoor activities that were experienced as being most affected by the traffic noise. Outdoor activities such as relaxation and conversation, as well as being able to be on the terrace or patio, were judged by half of the residents as being disturbed. Sleep quality was poorer in the exposed area. Residents experienced more difficulty in falling asleep, they awoke more often, and had poorer sleep quality and felt more tired in the morning. After the tunnel was built, sleep quality in the exposed area improved (less difficulties falling asleep, less tiredness during the morning) and no differences in comparisons with the control area could be observed.

The new studies confirm that road traffic noise leads to different symptoms and negatively affects well-being. The frequency of psycho-social symptoms was higher in the exposed area in 1997 compared to the control area (\( p < 0.05 \) Students t-test). After the traffic regulations, feelings of nervousness, irritation, uneasiness in the stomach and low social orientation were significantly reduced in the exposed area (\( p < 0.05 \) Wilcoxon test).

**CONCLUSIONS**

These longitudinal investigations confirm that exposure to high levels of road traffic noise not only induces adverse effects in terms of annoyance but also significantly affects sleep quality and psychophysiological health and well-being. Improved health and well-being as well as sleep quality and reduced annoyance can be achieved by an extensive reduction in road traffic.

**REFERENCES**

Stress Hormones in the Research on Cardiovascular Effects of Noise

W. Babisch

Department of Environment and Health, Federal Environmental Agency, 14191 Berlin, Germany

In recent years, the measurement of stress hormones including epinephrine, norepinephrine and cortisol has been widely used to study the possible increase in cardiovascular risk of noise exposed subjects. Since endocrine changes manifesting in physiological disorders come first in the chain of cause-effect for perceived noise stress, noise effects may be detected after relatively short periods of noise exposure in populations. This makes stress hormones a useful stress indicator, but regarding a risk assessment, the interpretation of endocrine noise effects is often a qualitative one rather than a quantitative one. Stress hormones can be used in epidemiological noise studies to study mechanisms of physiological reactions to noise and to identify vulnerable groups. A review is given about findings in stress hormones from occupational and environmental studies.

BACKGROUND
Traffic noise causes stress reactions similar to other stressors in the occupational and ambient environment [1]. In these situations of sympathetic and endocrine arousal, concentrations of stress hormones in the blood are increased and energy is mobilized in order to prepare the organism for fight-flight response to cope with the stressor. During sleep even low indoor levels of traffic noise are sufficient to bring about such reactions. Stress research in general as well as noise stress research has shown, that to a certain degree habituation leads to a reduction of acute stress effects even when the stressful situation remains unchanged. However, this kind of adaptive behavior may be associated in the long run with physiological costs. Short-term studies on acute noise effects give only limited insight into the long-term health effects. With regard to decision making in public health, findings from epidemiological studies deserve particular attention.

STRESS HORMONES
Although not being a risk factor as such (in epidemiological terms), stress hormones like epinephrine, norepinephrine and cortisol can be viewed as stress indicators. They play a crucial role in the metabolism of the organism where they act as biosmessengers and neuro-transmitters in the regulation of autonomic and other physiological functions. They are part of a complicated system of positive and negative feedback mechanisms affecting: the activity of the heart, blood pressure, blood lipids, blood glucose, blood clotting and blood viscosity. All these are established biological risk factors for hypertension, arteriosclerotics or myocardial infarction, considering the cause-effect chain, i.e.: sound - annoyance (noise) - physiological arousal (stress indicators) – changes in biological risk factors – morbidity – mortality [2,3]. The potential health hazard of noise may be underestimated in epidemiological studies if effect-modifying factors such as: effort, discomfort, informational content, predictability and controllability of the noise, the individual’s attitude towards the stressor and interactions with other stressors, are not taken into account. This has been shown in a large number of experimental studies on acute noise effects.

EPIDEMIOLOGICAL STUDIES
Table 1 gives an overview of the results of epidemiological studies. According to the model suggested by Ising [4], increases in norepinephrine levels are to be expected under habitual noise. This is a fairly consistent finding amongst studies on occupational noise. With regard to risk assessment in public health, findings from epidemiological studies may reflect chronic states of stress including processes of long-term compensation, habituation and physiological costs. However, the database appears too small to draw final conclusions. There are particular problems in the interpretation of findings for cortisol. This is because of the different biochemical methods applied for its measurement (total cortisol, free cortisol or metabolites of cortisol), and the marked circadian rhythms of hormone excretion.
Table 1. Epidemiological studies on the association between noise and stress hormones

<table>
<thead>
<tr>
<th>First Author</th>
<th>Year</th>
<th>Type of noise</th>
<th>Type of study</th>
<th>Noise exposure (Leq) [dB(A)]</th>
<th>Number of subjects</th>
<th>Epinephrine</th>
<th>Norepinephrine</th>
<th>Cortisol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manninen</td>
<td>1979</td>
<td>Occupational</td>
<td>CS</td>
<td>&lt;55, &gt;75</td>
<td>130 males</td>
<td>-</td>
<td>+</td>
<td>x</td>
</tr>
<tr>
<td>Ising</td>
<td>1980</td>
<td>Occupational</td>
<td>I</td>
<td>86-102, ear protection (approx. -13 dBA)</td>
<td>29 males</td>
<td>=</td>
<td>+</td>
<td>x</td>
</tr>
<tr>
<td>Rai</td>
<td>1981</td>
<td>Occupational</td>
<td>CS</td>
<td>“unexposed”, 88-107</td>
<td>110 males</td>
<td>x</td>
<td>x</td>
<td>+</td>
</tr>
<tr>
<td>Cesana</td>
<td>1982</td>
<td>Occupational</td>
<td>CS</td>
<td>“unexposed”, 90</td>
<td>45 males</td>
<td>=</td>
<td>+</td>
<td>x</td>
</tr>
<tr>
<td>Bolm-Audorff</td>
<td>1985</td>
<td>Occupational</td>
<td>CS</td>
<td>83-90, 91-97</td>
<td>39 males</td>
<td>(+)</td>
<td>(+)</td>
<td>=</td>
</tr>
<tr>
<td>Bolm-Audorff</td>
<td>1985</td>
<td>Occupational</td>
<td>I</td>
<td>83-97, ear protection (approx. -40 dBA)</td>
<td>39 males</td>
<td>=</td>
<td>+</td>
<td>=</td>
</tr>
<tr>
<td>Cavatorta</td>
<td>1987</td>
<td>Occupational</td>
<td>CS</td>
<td>&lt;78, 92-96</td>
<td>112 males</td>
<td>+</td>
<td>+</td>
<td>=</td>
</tr>
<tr>
<td>Melamed</td>
<td>1996</td>
<td>Occupational</td>
<td>I</td>
<td>85-95, ear protection (approx. -30 dBA)</td>
<td>35 adults</td>
<td>x</td>
<td>x</td>
<td>+</td>
</tr>
<tr>
<td>Sudo</td>
<td>1996</td>
<td>Occupational</td>
<td>CS</td>
<td>71-75, 93-100</td>
<td>75 males</td>
<td>+</td>
<td>+</td>
<td>(+)</td>
</tr>
<tr>
<td>Sudo</td>
<td>1996</td>
<td>Occupational</td>
<td>I</td>
<td>93-100, ear protection (approx. -29 dBA)</td>
<td>50 females</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ising</td>
<td>2000</td>
<td>Occupational</td>
<td>CS</td>
<td>&lt;86, 86-94, 95-102</td>
<td>47 adults</td>
<td>=</td>
<td>+</td>
<td>x</td>
</tr>
<tr>
<td>Babisch</td>
<td>1986</td>
<td>Road traffic</td>
<td>CS</td>
<td>51-55, 56-60, 61-65, 66-70 (outdoors, day)</td>
<td>2415 males</td>
<td>x</td>
<td>x</td>
<td>-</td>
</tr>
<tr>
<td>Babisch</td>
<td>1996</td>
<td>Road traffic</td>
<td>CS</td>
<td>45-75</td>
<td>195 females</td>
<td>=</td>
<td>+</td>
<td>x</td>
</tr>
<tr>
<td>Ising</td>
<td>2001</td>
<td>Road traffic</td>
<td>CS</td>
<td>30-54, 55-78 (max. level [dBC] indoors)</td>
<td>56 children</td>
<td>x</td>
<td>x</td>
<td>+</td>
</tr>
<tr>
<td>Evans</td>
<td>2001</td>
<td>Road + railway traffic</td>
<td>CS</td>
<td>&lt;50, &gt;60 (outdoors,day+night)</td>
<td>115 children</td>
<td>=</td>
<td>=</td>
<td>+</td>
</tr>
<tr>
<td>Schulte</td>
<td>1992</td>
<td>Low flying jet fighter</td>
<td>CS</td>
<td>Control area, 75m low flying area</td>
<td>60 adults</td>
<td>x</td>
<td>x</td>
<td>+</td>
</tr>
<tr>
<td>Evans</td>
<td>1995</td>
<td>Aircraft noise</td>
<td>CS</td>
<td>59, 68 (outdoors, day+night)</td>
<td>135 children</td>
<td>+</td>
<td>+</td>
<td>=</td>
</tr>
<tr>
<td>Evans</td>
<td>1998</td>
<td>Aircraft noise</td>
<td>CO+I</td>
<td>53, 62 (outdoors, day+night)</td>
<td>217 children</td>
<td>+</td>
<td>+</td>
<td>(+)</td>
</tr>
<tr>
<td>Ising</td>
<td>1999</td>
<td>Aircraft noise</td>
<td>CS</td>
<td>56, 70 (outdoors, daytime)</td>
<td>40 children</td>
<td>=</td>
<td>=</td>
<td>=</td>
</tr>
</tbody>
</table>

Relative effect under higher noise conditions: +: higher readings/increase, -: lower readings/decrease, =: no difference/no change, x: not measured, (): not significant

CS: cross-sectional, CO: cohort, I: intervention

REFERENCES


Aircraft noise, noise sensitivity, sleep and health

A. Smitha, S. Haywardb, S. Heatherleya and I. Diamondb

aCentre for Occupational and Health Psychology, Cardiff University
bSocial Statistics, University of Southampton

The present paper is concerned with clarification of the associations between perceptions of exposure to aircraft noise at night, noise sensitivity, noise-disturbed sleep and health problems. Structured interviews were conducted at areas around specified airports. A postal survey was also carried out. Results from both the interviews and the postal survey confirmed that it is important to focus on noise-disturbed sleep and health. Perceived sleep disturbance was associated with health problems. However, the direction of the causality cannot be determined from the current cross-sectional data. Further research must examine these issues using objective measures of noise, sleep and health. Changes in exposure, sleep and health must also be considered to allow clarification of the causal pathways.

INTRODUCTION

The aim of the present study was to examine relationships between perceptions of aircraft noise at night, noise sensitivity, noise-disturbed sleep, personality and subjective health. In a previous community survey [1, 2] we have found that the associations between noise, noise sensitivity and health can largely be accounted for by the personality trait of negative affectivity. However, the association between noise-disturbed sleep and health was still significant when negative affectivity was co-varied. These data were collected in an area with low aircraft noise exposure and the present study was carried out in areas close to several UK airports in order to determine whether a similar pattern of results is obtained when aircraft noise exposure is higher. In addition, data were collected by both questionnaire and interview to determine whether similar profiles were obtained using different methods. Further background information is given in a more detailed report [3].

METHODS

Approximately 300 interviews were conducted near four airports (Heathrow, Manchester, Gatwick and East Midlands). Half of these were in areas with high aircraft noise at night and the others in areas with low exposure. The postal survey was sent to a random sample of the population in the regions close to Heathrow, Manchester, Coventry and East Midlands airports. In each area two sites were chosen, so as to reflect areas of relatively high and low night noise at that airport. Questionnaires were sent to 600 addresses at each site.

The interview assessed self-report health, noise sensitivity, noise disturbed sleep and negative affectivity. The questionnaire provided more detailed information on these topics.

RESULTS

The sample sizes for the interviews and postal questionnaire were as follows:

Interviews: High noise exposure N = 589
Low noise exposure N = 632
Questionnaires: High noise exposure N = 289
Low noise exposure N = 369

Perception of aircraft noise when trying to get to sleep

In both the interview and postal data there was a significant difference between low and high noise areas in the frequency of noticing aircraft noise when trying to get to sleep. These effects are shown in Table 1.

Aircraft noise exposure and sleep disturbance

There was significantly greater sleep disturbance in the high aircraft noise areas (see Table 1).

Aircraft noise exposure and health

Both the interview and questionnaire studies revealed greater mental health problems in the high noise areas. Physical health problems were only found more frequently in the high aircraft noise area in the questionnaire survey (see Table 1).

Noise sensitivity and health

High noise sensitivity was associated with greater sleep disturbance, mental health problems and acute symptoms in both the questionnaire and interview data (see Table 2).

Sleep disturbance attributed to aircraft noise and health

Sleep disturbance attributed to aircraft noise was associated with greater health problems. This was true for both the postal questionnaire and interviews (see Table 3).
**Co-varying age and negative affectivity**

Co-varying age and negative affectivity removed all the significant effects of noise exposure and noise sensitivity on health. However, the effects of noise-disturbed sleep were still significant.

**Table 1.** Results from the interviews and postal questionnaire (scores are the means, s.d.s in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>High noise</th>
<th>Low noise</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Noise when sleeping: Interview¹:</td>
<td>2.59 (1.13)</td>
<td>2.08 (1.06)</td>
<td>P&lt;0.00001</td>
</tr>
<tr>
<td></td>
<td>2.09 (1.20)</td>
<td>1.38 (1.15)</td>
<td></td>
</tr>
<tr>
<td>2 Noise and sleep Interview²:</td>
<td>8.18 (4.3)</td>
<td>6.07 (3.4)</td>
<td>P&lt;0.00001</td>
</tr>
<tr>
<td></td>
<td>5.01 (4.2)</td>
<td>2.70 (3.4)</td>
<td></td>
</tr>
<tr>
<td>3 Noise and health Interview³:</td>
<td>1.75 (1.1)</td>
<td>1.41 (0.6)</td>
<td>p&lt;0.0005</td>
</tr>
<tr>
<td></td>
<td>1.58 (0.8)</td>
<td>1.20 (0.5)</td>
<td>p&lt;0.0005</td>
</tr>
<tr>
<td></td>
<td>1.32 (0.08)</td>
<td>1.13 (0.5)</td>
<td>p&lt;0.0005</td>
</tr>
<tr>
<td></td>
<td>1.29 (0.7)</td>
<td>1.11 (0.5)</td>
<td>p&lt;0.0005</td>
</tr>
<tr>
<td></td>
<td>4.19 (4.3)</td>
<td>3.28 (3.4)</td>
<td>p&lt;0.00005</td>
</tr>
<tr>
<td></td>
<td>2.77 (2.2)</td>
<td>2.28 (2.1)</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>5.11 (3.7)</td>
<td>4.18 (3.4)</td>
<td>p&lt;0.005</td>
</tr>
</tbody>
</table>

1: Scale 1 to 5, never to often
2: Scale 0 to 4, never to often
3: High scores more sleep disturbance, max = 20
4: High scores more sleep disturbance, max = 16
5: Scale 1 to 5, never to very often
6: High scores=more health problems, max = 15
7: High scores=more health problems, max = 22

**Table 2.** Noise sensitivity, sleep and health (Scores are the means, s.d.s in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Low sensitive</th>
<th>High sensitive</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviews:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep disturbance</td>
<td>3.28 (3.7)</td>
<td>4.21 (4.1)</td>
<td>p&lt;0.0005</td>
</tr>
<tr>
<td>Anxious</td>
<td>1.33 (0.8)</td>
<td>1.47 (0.6)</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>14 day health¹</td>
<td>0.2 (0.5)</td>
<td>0.3 (0.6)</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Post questionnaire:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep disturbance</td>
<td>6.90 (3.9)</td>
<td>7.37 (4.1)</td>
<td>p&lt;0.00001</td>
</tr>
<tr>
<td>GHQ</td>
<td>2.97</td>
<td>4.34</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>14 day health</td>
<td>4.1 (3.5)</td>
<td>5.1 (3.6)</td>
<td>p&lt;0.001</td>
</tr>
</tbody>
</table>

1: 0 = no health problems, 1 = health problems

**Table 3.** Noise-disturbed sleep and health (Scores are the means, s.d.s in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>High sleep disturbance</th>
<th>Low sleep disturbance</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interview:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritable</td>
<td>2.18 (1.2)</td>
<td>1.06 (0.3)</td>
<td>P&lt;0.00001</td>
</tr>
<tr>
<td>Anxious</td>
<td>1.82 (1.2)</td>
<td>1.03 (0.2)</td>
<td>P&lt;0.00001</td>
</tr>
<tr>
<td>Depressed</td>
<td>1.48 (0.9)</td>
<td>1.01 (0.1)</td>
<td>P&lt;0.00001</td>
</tr>
<tr>
<td>Sad</td>
<td>1.43 (0.8)</td>
<td>1.01 (0.1)</td>
<td>P&lt;0.00001</td>
</tr>
<tr>
<td>Postal:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHQ</td>
<td>4.45</td>
<td>2.85</td>
<td>P&lt;0.00001</td>
</tr>
<tr>
<td>12 month health</td>
<td>2.92 (2.1)</td>
<td>2.10 (2.1)</td>
<td>P&lt;0.00001</td>
</tr>
<tr>
<td>14 day health</td>
<td>5.26 (3.5)</td>
<td>4.00 (3.5)</td>
<td>P&lt;0.00001</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Overall, the present study has shown that high exposure to aircraft noise and noise sensitivity are associated with health problems. These associations, however, are removed when the personality trait of negative affectivity is co-varied. Noise-disturbed sleep is also associated with greater health problems and these effects do not reflect negative affectivity. These results confirm findings from earlier studies [1, 2] and further research using a longitudinal design must now be conducted as the present cross-sectional analyses do not allow one to infer causality. Similarly, objective measurement of noise exposure and sleep is required to determine whether the above effects merely reflect subjective reports or can be confirmed objectively.

**ACKNOWLEDGEMENT**

The research described in this paper was supported by the Department of Environment, Transport and the regions.

**REFERENCES**

The Role of Noise Source Visibility in Psychological and Physiological Effects of Noise Exposure


Department of Psychology, The University of Sydney, Australia, 2006
Department of Architecture, The University of Sydney, Australia, 2006
Department of Public Health, The University of Sydney, Australia, 2006

Various studies have identified the role of psychological and situational factors in reaction to noise, and other consequences of noise exposure. Because negative attitudes to the noise source are associated with worse reaction, residents who can see the airport from their homes may have worse reactions. As a part of the Sydney Airport Health Study, 80 residents in the vicinity of Sydney airport completed an interview which assessed reaction to aircraft noise (general reaction - dissatisfaction and affectedness, and annoyance), and physical and mental responses (e.g. general health, substance use, panic, anxiety and depression), as well as visibility of the airport from the home. Residents who could see the airport were compared to those who could not in terms of responses to noise exposure. Only a small proportion of the sample could see the airport, and airport visibility appeared to have no influence on response to aircraft noise.

INTRODUCTION

Several psychological factors have been found to influence response to noise at least as much as noise exposure [1,2,3]. Thus, prediction of response for regulatory (and other) purposes will be more accurate if the role of such factors is understood and considered, rather than if based solely on dose-response curves.

Attitudes toward the noise source are an important modifier of reaction to noise [1,2,3,4]. That is, individuals with negative attitudes toward the noise source demonstrate worse reaction to the noise than do individuals who are less negatively disposed toward the noise source. For example, an individual who feels that airport authorities do not care about the impacts of aircraft noise is more likely to be annoyed by aircraft noise than is an individual who feels that airport authorities are doing all they can to minimize these impacts.

In the present paper we are investigating the impact of airport visibility on reaction to aircraft noise (while considering possible confounding by noise exposure). Airports are typically unsightly, and so individuals who can see the airport from their homes have potentially more negative attitude toward the airport than people who can not. They may thus react more negatively to aircraft noise. Being able to see the airport may also make aircraft noise more salient and so sensitise residents more to the impacts of noise.

METHODS

Subjects and sampling

Participants were 80 (of 220) residents of areas selected on the basis of location relative to Sydney (Kingsford Smith) Airport to produce a 2x2 design; noise exposure prior to runway reconfiguration was "high" or "low", and noise exposure after reconfiguration (when the present data was collected) had either changed (decreased or increased, respectively) or not changed. The four areas thus produced - "high to high", "high to low", "low to low", "low to high" - were approximately equally represented in the sample. From a random starting point within each area, every 7th residence along a predetermined path was approached, and one respondent selected within each household using the "last birthday" technique, without replacement.

Materials

Participants completed a structured interview (based on previous socioacoustic surveys [5,6] and pilot results) and several self-completion questionnaires. Respondents indicated whether they could see the airport from inside or outside their home. General reaction was computed from ratings of dissatisfaction with, and affectedness by, aircraft noise on a
thermometer marked with numbers from 0 to 10 and an associated verbal scale ("none", "a little", "moderate", "a lot", "very much"). Annoyance was assessed using 3 items. General health, substance use, and experience of panic, were assessed using relevant checklists. Depression and anxiety were assessed using the Profile of Mood States (POMS) self-completion questionnaire.

**Procedure**

After a letter was sent to every selected residence announcing the investigation, trained interviewers door-knocked at selected residences and asked to speak to the person over 18 living at the residence who had last had a birthday. When a suitable individual agreed to participate, the structured interview was conducted in the home and questionnaires were completed by the subject while the interviewer waited.

**RESULTS**

2 respondents in each of the initially low noise areas, and 1 respondent in each of the initially high noise areas, could see the airport from their home.

<table>
<thead>
<tr>
<th>Table 1. Mean (with s.d.) reaction, general health, substance use, panic, depression and anxiety, with the t-value and significance of the comparison between respondents who can versus can’t see the airport.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Can see</strong></td>
</tr>
<tr>
<td>General reaction</td>
</tr>
<tr>
<td>Annoyance</td>
</tr>
<tr>
<td>General health</td>
</tr>
<tr>
<td>Substance use</td>
</tr>
<tr>
<td>Panic</td>
</tr>
<tr>
<td>Depression</td>
</tr>
<tr>
<td>Anxiety</td>
</tr>
</tbody>
</table>

Insuff=insufficient cases in “can see” group for reliable t-test

**DISCUSSION AND CONCLUSIONS**

Individuals who reported being able to see the airport from their homes did not appear to differ from those who could not see the airport in terms of psychological or physiological response to aircraft noise.

Concerns regarding confounding of airport visibility with noise exposure should be allayed by findings that the proportion of respondents who could see the airport was the same in areas with low and high noise exposure at the time of the present interview (after runway reconfiguration).

In sum, the present findings suggest that airport visibility has minimal impact on response to aircraft noise (and perhaps attitude to the noise source). However, these results should be treated cautiously in view of the small proportion of respondents who reported being able to see the airport from their homes. The only response which appears likely to have shown an effect in a larger sample was anxiety, with those who could see the airport being somewhat less anxious (perhaps because they have a more available account of the noise).

**ACKNOWLEDGMENTS**

The authors gratefully acknowledge funding by the Federal and Sydney Airports Corporation (of Australia).

**REFERENCES**

MILITARY LOW FLYING AND HEARING – METHODOLOGICAL ISSUES IN THE ASSESSMENT OF HIGH FREQUENCY HEARING PERFORMANCE

Peter. D. Wheeler

University of Salford, M5 4WT, UK, +44 161 295 3030(tel)/5427(fax), p.d.wheeler@salford.ac.uk

ABSTRACT

The recent literature contains a number of reports of apparent hearing loss allegedly due to exposure to the noise of low flying military aircraft. In some of these studies, the emphasis has been on high-frequency hearing, where it has been suggested that, for transient noises such as fast jet overflights, the first signs of noise-induced hearing loss might be found. Audiometric testing at frequencies up to 16 kHz has been used to generate comparative hearing level data and derived relative-risk ratios. We have identified some key issues relating to measurement protocols. These include the influence of background noise in field studies and the evaluation of measurement uncertainties. Importantly, inter-subject variance in concha-cardrum transfer function at high audio frequencies has emerged as a source of concern in the comparative assessment of hearing using headphone-presentation pure-tone audiometry above 10 kHz. This factor may be a major confounding constraint in the judgement of alleged cases of high-frequency hearing loss as an early indicator of noise-induced hearing damage in overflown populations.

INTRODUCTION

This paper addresses the subject of the methodology of field and laboratory studies of auditory effects, in particular high frequency hearing acuity. In 1997, we were asked to review and analyse reports (1) alleging permanent hearing loss at high frequencies in young children living in areas of Germany where, prior to 1990, military low flying took place. In these studies, the high-frequency hearing, at frequencies of up to 16 kHz, of young children and teenagers in various regions of Germany was investigated, using field measurements made in mobile audiological laboratories or in their schools.

HIGH FREQUENCY HEARING

There was considerable interest in high frequency audiometry (HFA) in the 1960s, with the widespread expectation that early warning of noise induced hearing loss at conventional frequencies could be detected by examination of high frequency hearing acuity. The audiometric earphone technology of the time was not capable of application to HFA, and it was only with the advent of HiFi headphones in the 1970s that HFA began to be used more widely. Only in recent years has agreement been reached on “normal” hearing at high frequencies. The wide range of hearing levels at 10kHz upwards is apparent, even for nominally non-exposed young adults, in recent studies by Han and Poulseen (2) and Richter (3), whose work has led to the publication of ISO TR/389-5 (4). Using the Sennheiser HDA200 circumaural earphone, Han and Poulseen found a standard deviation of 16.8 dB (range 72 dB) at 16kHz for 62 ears. Richter found a similar pattern (sd 16.6 dB, range 65 dB at 16 kHz).

MEASUREMENT UNCERTAINTIES

The chief sources of measurement uncertainty in HFA are calibration variance, subjective variance (number of trials, the slope of the psychometric function, the psychophysical test procedure used, the consistency of the subject’s attention and their personal criterion for audibility – which may change from test to test or with frequency) and fitting variance (the variability in sound level presented to the subject’s ear arising from the placement of the headphone on or over the subject’s ear). We have examined, assessed and quantified the likely magnitude of these sources of uncertainty. There is little space here to discuss our findings other than to mention the particular difficulties associated with children as new test subjects at high frequencies and the need for realistic simulation of the headphone/ear interaction when investigating headphone placement effects. High frequency test sounds are unusual auditory signals and it is important that the subject should be very familiar with the nature of the test sounds, by adequate training.

A further source of difficulty in comparing absolute high frequency hearing levels in young children is the dependence of hearing level at these high frequencies on the geometry of the ear canal and concha (5), which might be presumed to yield systematic differences between groups of children of different ages.
DYNAMIC RANGE LIMITATIONS

Because of the huge range in hearing at HF, there can be severe dynamic range problems. Zero dB HL at 16 kHz for the Sennheiser HDA200 high frequency audiometric headphone is 56 dB SPL (referred to the IEC 318 coupler) and one can expect to find “normal” subjects with thresholds approaching 100dB SPL. Subjects with HF hearing loss will have even higher thresholds. Although the determination of high frequency hearing thresholds is unlikely to be directly affected by background noise when using a circumaural headphone, indirect masking by mid frequency background noise may adversely affect the reliability of measurements.

Importantly, we have established that, in the case of the HFA studies carried out in Germany, background noise limitations prevented any hearing level measurements being made below +10 dB HL, or even +20 dB HL for some of the groups of children tested. Screening out those subjects who have real elevated thresholds is a reasonable experimental technique, but it is vital that the level of any extraneous and unwanted masking noise at the subject’s ear at the time of testing is known. Otherwise, the data collected by such means will comprise an unknown mix of real elevated thresholds and non-elevated thresholds masked by the instantaneous external noise.

HIGH FREQUENCY TRANSFER FUNCTION

A major factor at high frequencies is the transfer function of the ear canal, from concha to eardrum. It is determined by the physical geometry of the ear canal, which varies considerably between people in its effects at high frequencies. Our experimental work has sought to examine the fine structure of the high frequency audiometric response. Because the subject is required to bring a high level of concentration and consistency to the task, which in experimental terms, lasts for several hours, young adult subjects, with normal hearing, were chosen. Data from this study, to be presented, have allowed us to conclude that the comparison of subjects at just a few high test frequencies, using the conventional pure-tone (sine wave) audiometric signal, is not likely to give a fair picture of their comparative high frequency hearing acuity.

CONCLUSIONS

Recent studies by several researchers have yielded consistent information for the high frequency hearing of young adults. A wide range of hearing acuity is observed. Serious experimental deficiencies can result from dynamic range limitations when background noise is not controlled sufficiently. It is important in field studies that efforts are made to determine high frequency hearing acuity more reliably than has been the case in some recent studies. Absolute and masked threshold data must be separable.

Addressing the issue of high frequency audiometry, firstly the stability and absolute calibration of the test signal frequency in an audiometer is important at these high frequencies. Secondly, and importantly in the context of the assessment of Hartmut Ising’s work, we must consider how this fine detail of threshold frequency-dependency at high frequencies can affect our judgement of whether a subject has “normal” or “impaired” hearing. An apparent (relative) hearing deficiency at 14 kHz or 16 kHz may be a real indication of impairment across a range of frequencies, or may be an irrelevant resonance effect. Perhaps, when relatively large numbers of subjects are involved, such fine-structure issues are averaged out. However, we suggest that judgements about apparent differences in hearing acuity at these high frequencies between individuals, or small groups of subjects, are of doubtful reliability because of this phenomenon. This is particularly of concern in the case of young children, whose ear canals are still growing.

REFERENCES


This work was supported by the UK Ministry of Defence (MOD), however the views expressed in this paper are based on the professional experience of the authors and may neither reflect the MOD’s view nor be binding on the Ministry.
A Critical Assessment of Methods for Calculating Onset Rate and their Role in Predicting Acoustic Reflex Attenuation

G. Kerry\textsuperscript{a}, C. Lomax\textsuperscript{a} and D. J. James\textsuperscript{b}

\textsuperscript{a}University of Salford, Salford M5 4WT, UK
\textsuperscript{b}HQ PTC, RAF Innsworth, Gloucester, GL3 1EZ, UK

A crucial factor when considering the effect of fast transient noise sources on the human ear is the response of the acoustic reflex, which provides protection to the inner ear. When assessing how the acoustic reflex will respond, the signal onset rate has to be considered. The potential importance of this has been acknowledged by the World Health Organisation [1], and a draft standard has included an adjustment for onset rate [2]. A previous paper by the authors [5], referenced in [1] highlighted the existence of several methods for calculating onset rate, which, when assessed, gave significantly different values for the same transient. Here, current methods of measuring onset rate are compared, including a new method which accounts for the response of the acoustic reflex to a fast transient using an ultra short $L_{\text{Aeq}}$ time history. An assessment of methods for calculating onset rate is carried out and their role in predicting reflex attenuation is discussed.

**INTRODUCTION**

The Acoustic Reflex is a complex mechanism, which provides protection to the inner ear only when the signal level exceeds the Acoustic Reflex Threshold (ART). Above ART, its response is defined by the onset characteristics of the stimulus. Onset rate, a measure of the rate of rise of the signal, can be used to predict the likely attenuation provided by the acoustic reflex for fast transient signals [3]. There are several methods of calculating onset rate, which give different values when applied to the noise from low flying military aircraft [4, 5]. This paper compares the results of applying these methods to other transient noise sources found in the community.

**ONSET RATE CALCULATION METHODS**

Seven methods assessed in [5] and defined briefly below, have been used in this study:

\textbf{NPL:} dy/dt over the 40dB leading up to the $L_{\text{Amax}}$

\textbf{USAF A:} dy/dt between time the signal first exceeds the ambient level by 5dB and the time the signal first exceeds a level 5dB below its maximum.

\textbf{USAF B:} dy/dt over a reasonably constant portion leading up to the maximum (replaces USAF A when gradient varies during the rise of the event).

\textbf{ANSI:} dy/dt between time the signal first exceeds the ambient level by 10dB and the time the signal first exceeds a level 10dB below its maximum.

\textbf{German A:} dy/dt calculated between 15dB and 5dB below the maximum.

\textbf{German B:} dy/dt in stepeastest 10dB interval.

\textbf{German (Ising) C:} similar to German B except the 10dB interval must occur above 80dB.

**The Ultra Short $L_{\text{Aeq}}$ Onset Rate**

An additional method accounts for the way the acoustic reflex responds when exposed to the complex slope characteristics found in real signals, by allowing for the variation of the envelope above the curve. The calculation requires the rise portion of the signal to be sampled, at a rate that will provide an accurate snapshot of the rise of the event, using short $L_{\text{Aeq}}$. Only the portion of the signal which exceeds ART is accounted for, reflecting the way the ear responds. This is the most critical portion of the waveform, and its characteristics will determine the degree of reflex protection to exposure from a loud transient. A full definition of the method can be found in [3].

**RESULTS**

The methods of calculating onset rate were used to evaluate the onset rate of five loud transient signals, that had similar onset characteristics to the noise from low flying military aircraft: often rising to high levels, but not normally considered ‘impulsive’ like gunfire and some industrial sources. A typical signal from a low flying Tornado was included.

A) Children shouting in unison in school assembly
B) Crowd cheering a goal at a sports event
C) Two carriage train passing through station without stopping at high speed
D) Truck passing car parked with window open
E) Opening car window on a busy motorway
F) Tornado aircraft flying at 227 feet and 427 knots

High quality recordings were made of each source. The short $L_{\text{Aeq}}$ (10ms) time histories of the onset portion of each are shown in figure 1, along with the smoothed running average (100ms), as used to calculate the ultra short $L_{\text{Aeq}}$ onset rate.
DISCUSSION AND CONCLUSION

Figure 2 provides a summary of the calculated onset rates. The methods that concentrate on the top portion of the waveform (USAF B, German A & C) give relatively lower results for convex waveforms (children), and higher results for concave signals (i.e. Tornado, train). German B always gives the highest/equal highest value (except for crowd). The ANSI, USAF A and NPL methods tend to give comparable results, except when the ANSI method’s sampling criteria mean it has been calculated using a faster sampling rate. These methods all take a simple gradient between two points on the time history, not necessarily giving a true picture. The ultra short $L_{\text{Aeq}}$ method gives relatively high values for signals which cross the acoustic reflex threshold (ART) at a fast rate (i.e. train, children). It is the only method that takes account of the rise characteristics of the full waveform, above ART. An earlier study proposed that a suitable method of calculating onset rate, in conjunction with the A-weighted maximum level, could be used to predict the attenuation provided by the acoustic reflex [3]. Using the ultra short $L_{\text{Aeq}}$ definition for onset rate, provides a more consistent method to assess the complex characteristics of fast transient noise sources.

ACKNOWLEDGEMENTS

This work was supported by the UK Ministry of Defence (MOD), however the views expressed in this paper are based on the professional experience of the authors and may neither reflect the MOD’s view nor be binding on the Ministry.

British Crown Copyright 2001/MOD. Published with the permission of Her Britannic Majesty's Stationary Office.

REFERENCES

Interrelationships Between Reaction to Noise, Noise Sensitivity, Prior Knowledge of Noise, and Residential Satisfaction

R.F.S. Job², J. Hatfield³, N.L. Carter², P. Peploe, R. Taylor³ and S. Morrell³

²Department of Psychology, The University of Sydney, Australia, 2006
³Department of Architecture, The University of Sydney, Australia, 2006
¹Department of Public Health, The University of Sydney, Australia, 2006

“Noise sensitivity” may influence community reaction to noise. More noise sensitive individuals may choose to live in quiet areas, so undermining the apparent relationship between noise exposure and response. Prior knowledge of noise levels may modulate this influence of sensitivity, as well as influencing residential satisfaction. Residential satisfaction may, in turn, influence reaction. These interrelationships were investigated as part of the Sydney Airport Health Study (N=505). Reaction to aircraft noise (dissatisfaction and affectedness), aircraft noise-induced disturbance to activities (e.g. conversation and sleeping), noise sensitivity, prior knowledge of noise levels, and residential satisfaction (consideration of moving, and direct rating) were assessed in a socioacoustic survey in high and low noise areas in the vicinity of Sydney airport. Results are discussed in terms of the role of psychological factors in reaction to noise, and the relevance of sensitivity to the dose-response relationship.

INTRODUCTION

It has been suggested that the relationship observed between reaction to noise and noise exposure in socioacoustic surveys may be undermined by self-selection of noise sensitive individuals into low noise areas [1]. Because noise sensitivity is positively associated with reaction to noise [2] this would have the effect of lowering apparent reaction to high noise, and increasing the apparent reaction to low noise. However, the association between noise sensitivity and noise exposure which is required for this argument is generally not observed [2]. Perhaps self-selection does not occur because people are not aware of noise levels in their chosen residential area, and are reluctant to move once living there. Prior knowledge of noise levels may also influence reaction via residential satisfaction. Psychological factors influence reaction to noise at least as much as noise exposure itself [2,3]. People who choose a residential area knowing about high noise levels in that area are less likely than others to be dissatisfied with the area, and so may be less tolerant of noise experienced in the area. Knowledge may also have a more direct effect on reaction: unexpected noise is likely to be more unpleasant than unexpected noise [4]. Interrelationships between noise exposure, noise sensitivity, prior knowledge of noise levels, and response (dissatisfaction and activity disturbance) were assessed in the present study.

METHODS

Subjects and sampling

Subjects were 505 residents of areas selected on the basis of location relative to Sydney (Kingsford Smith) Airport. Areas with “high” or “low” noise exposure were approximately equally represented. From a random starting point within each area, every 7th residence along a predetermined path was approached, and one respondent selected within each household using the “last birthday” technique, without replacement.

Materials

Respondents completed a structured interview (based on previous socioacoustic surveys [5,6] and pilot results) and several self-completion questionnaires. They indicated whether they were aware of the noise levels in the area before they moved in and rated their overall satisfaction with their neighbourhood (1=“very good” to 5=“very bad”). Noise sensitivity was assessed by having subjects rate their annoyance with 12 “loud” and “quiet” noise situations (e.g. someone rustles paper at the movies) using a card depicting a thermometer marked with numbers from 0 to 10 and an associated verbal scale (“none”, “a little”, “moderate”, “a lot”, “very much”). Respondents
estimated the extent to which they were i) affected by and ii) dissatisfied with aircraft noise, again using the “opinion thermometer”. Subjects also indicated whether 12 activities were disturbed by aircraft noise.

RESULTS

In the high noise area 65.3% respondents reported knowing about noise levels before they moved in, compared to 16.2% in the low noise areas.

Table 1. Relationship of noise exposure (ANEI) with noise sensitivity, residential satisfaction, reaction, & activity disturbance, for respondents who knew versus didn’t know about noise levels, across both areas

<table>
<thead>
<tr>
<th></th>
<th>Knew</th>
<th>Didn’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity to loud noises</td>
<td>-.038</td>
<td>-.069</td>
</tr>
<tr>
<td>Sensitivity to quiet noises</td>
<td>-.037</td>
<td>-.026</td>
</tr>
<tr>
<td>Residential satisfaction</td>
<td>-.019</td>
<td>-.028</td>
</tr>
<tr>
<td>General reaction</td>
<td>.341**</td>
<td>.531**</td>
</tr>
<tr>
<td>Annoyance</td>
<td>.355**</td>
<td>.523**</td>
</tr>
<tr>
<td>Activity disturbance</td>
<td>.439**</td>
<td>.578**</td>
</tr>
</tbody>
</table>

Table 2. Mean (with s.d.) residential satisfaction, reaction, & activity disturbance, for respondents who knew versus didn’t know about noise levels, in the high & low noise areas separately.

<table>
<thead>
<tr>
<th></th>
<th>High Knew</th>
<th>Did’t Know</th>
<th>Low Knew</th>
<th>Did’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential satisfaction</td>
<td>(75)</td>
<td>(70)</td>
<td>(81)</td>
<td>(93)</td>
</tr>
<tr>
<td>General reaction</td>
<td>(2.53)</td>
<td>(2.35)</td>
<td>(1.90)</td>
<td>(2.46)</td>
</tr>
<tr>
<td>Annoyance</td>
<td>(6.87)</td>
<td>(7.97)</td>
<td>(2.95)</td>
<td>(3.53)</td>
</tr>
<tr>
<td>Activity disturbance</td>
<td>(2.22)</td>
<td>(2.25)</td>
<td>(2.09)</td>
<td>(2.48)</td>
</tr>
<tr>
<td>Activity disturbance</td>
<td>(2.76)</td>
<td>(2.79)</td>
<td>(2.02)</td>
<td>(2.85)</td>
</tr>
</tbody>
</table>

The correlation between exposure and response for people who knew about the noise versus people who didn’t, did not differ significantly. In high noise areas, respondents who reported knowing about noise levels before they moved in had lower general reaction ($t_{232}=2.72, p=.007$) and annoyance ($t_{231}=2.89, p=.004$) than those who didn’t. No significant differences were observed in low noise areas. Residential satisfaction was significantly related to general reaction and annoyance in high noise areas ($r=.144, p=.021, r=.159, p=.011$, respectively). No further correlation of residential satisfaction with reaction or activity disturbance was significant in high or low noise areas or overall (highest nonsignificant $r=.104, p=.109$).

DISCUSSION AND CONCLUSIONS

The common finding that sensitivity does not relate to exposure [2] was replicated. The obvious explanation in terms of lack of knowledge about noise levels combined with a reluctance to move, was not supported by the present results. Thus, lack of knowledge regarding personal noise sensitivity (combined with a reluctance to move), or unrealistic optimism about personal capacity to withstand the effects of noise [7] may be a better explanation of the failure to self select. In high noise areas, knowledge appeared to afford some protection against the impacts of noise. That is, reaction was lower for people who knew the noise before they moved than for those who didn’t. Unsurprisingly, this moderating effect of knowledge was not observed in low noise areas in which reaction is negligible anyway. The effect of knowledge does not appear to be mediated by sensitivity (see above) or by residential satisfaction (which was not associated with knowledge), and so may be a more direct effect [see 4]. Nonetheless, residential satisfaction was related to reaction, in high noise areas only (again perhaps due to restricted range of reaction in low noise areas).

ACKNOWLEDGMENTS

The authors gratefully acknowledge funding by the Sydney Airports Corporation, Australia.

REFERENCES

1. B. Berglund and T. Lindvall, Community Noise (Archives of the Center for Sensory Research, Stockholm, 1995).
Annoyance due to combined noise sources – advanced results

C. Cremezi\textsuperscript{a}, P.E. Gautier\textsuperscript{a}, J. Lambert\textsuperscript{b}, P. Champelovier\textsuperscript{b}

\textsuperscript{a}, SNCF, Direction de la recherche et de la technologie, SFC, 45, rue de Londres, 75379 Paris cedex 08, France
\textsuperscript{b}, INRETS, LTE, 25 av. François Mitterand, case n°24, 69675 Bron cedex, France

In order to improve our knowledge of transport noise annoyance in case of double developments of infrastructure (a road near a railway line, in our case), a national socio-acoustic survey has been carried out in France, on 63 different multi-exposed locations. These locations were exposed to motorways and highways, with a large range of lorries, and railways with high speed trains or mixed lines (freight and passenger), in rural and sub-urban areas.

Both objectives of this study were to reassess annoyance in practical situations through a large combination of multisource situations (including dominant sources), and to determine the effects of several noise sources on the overall annoyance perceived. Main results, as the whole methodology, will be detailed in a synthesis report which is well advanced.

In the present paper, we insist on confirmation of the railway bonus, interaction between sources, and total annoyance results.

\textbf{INTRODUCTION}

Multi-exposure is a complicated problem combining several aspects (interactions between sources, expression of the total annoyance…) that our survey has allowed us to study. In [1], the influence of exposure situation on a source annoyance has been detailed, some comparisons have been presented, and differences between day and night total annoyance have been shown.

In the present paper, a difference between railway and road noises which is the railway bonus will be discussed. Source interactions will be investigated, and some results on total annoyance presented.

\textbf{ABOUT POPULATION SURVEYED AND ANNOYANCE EVALUATION}

700 interviews have been made, with a good representativeness of the French population in terms of sex, age and activities. 79 % of the residents were living in individual houses. All the persons were exposed to both sources, but some of them were exposed to a dominant source (5 dB more than the other source), and some to both sources at similar levels (the difference is less than 5 dB).

Annoyance was evaluated by people on a 11 point scale (0 is not at all annoyed, and 10 is extremely annoyed), and when the note was greater than 5, the person was considered “quite or highly annoyed”.

\textbf{RAILWAY AND ROAD NOISE COMPARISON : ABOUT BONUS}

In this study, dose/response relations are modelled by logistic regression, and the probability of being “quite or highly annoyed” is assessed. Railway bonus (for an equal sound level, railway annoyance is less than the road one) has often been cited [2] [3], giving a bonus around 5 dB(A). A possibility of “using” multi-exposed people is to consider that they can make a good comparison of sources annoyance, as they are exposed to both, and compare sources without taking into account any interaction. Results obtained figure1, are in line with references, with a railway bonus which can be greater than 5 dB, above 60 dB(A).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{dose/response for road and rail sources, for the 24 h period}
\end{figure}

If now, the exposure situation is taken into account, well different curves are obtained for dominant and no dominant situations (figure 2), showing that the

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{rail and road annoyance, according to exposure situation, in period 24h}
\end{figure}
approximation of monoexposure can’t be done. In dominant situations, railway and road annoyances are well distinguished and a more important railway bonus is found, till 75 dBA. In no dominant situations, both annoyances are not so different, but above 60 dB(A), annoyances become greater than in dominant situations.

**INTERACTIONS BETWEEN RAIL AND ROAD NOISE**

When the answer to the question “when the train comes past, I hear less road noise” is considered with the exposure situation, it could be seen that railway noise masks road noise, as the percentage of agreed persons becomes less that 50% only in great road dominance (dr2) (figure 3). The same kind of curves also suggests that railway noise could be contaminated by road noise.

![Figure 3](image)

**FIGURE 3** : "when the train comes past, I hear less road noise", % of agreed persons, period 24 h

**TOTAL ANNOYANCE**

![Figure 4](image)

**FIGURE 4** : total annoyance according to global levels and source levels, in dominant situations

Studying exposure situation influence for total annoyance, it is shown in figure 4, that in dominant situations, total annoyance expressions according to global noise level or dominant source level, are quite the same. This situation is very similar to mono-exposure.

Another approach is to fix global level, and see the total annoyance evolution, according to railway and road level contribution, for different global levels.

![Figure 5](image)

**FIGURE 5** : total annoyance according to rail and road levels, for global level less than 60 dB(A), and more than 70 dB(A).

Results are really different for global level between 60 and 70 dB(A), and other levels for which there’s no real correlation between total annoyance and sources contribution (figure 5). On the contrary, for global levels between 60 and 70 dB(A), it is found that total annoyance is lower when the rail level contribution increases (figure 6).

![Figure 6](image)

**FIGURE 6** : total annoyance according to railway and road levels, for global level between 60 dB(A), and 70 dB(A).

**CONCLUSION**

Dose/response curves presented in this paper confirm the existence of the rail bonus, but also show the existence of interactions between rail and road sources, and the necessity of taking into account exposure situations. Considering total annoyance, the particular importance of the “medium” levels, between 60 and 70 dB(A) was also evidenced.

Complementary studies appear necessary in order to be able to take into account these different results into a general multiexposure annoyance criterion.

**REFERENCES**

Effects of Noise on Human Health

M. Metin Donma a and Orkide Donma b

Environmental problems, increasing population, technological developments, economical difficulties all, affect the psychosocial organization of the people. A well-controlled acoustic environment during childhood will ensure the future population with psychological well-being. The child, a developing organism, is vulnerable to physical and chemical pollution. Further discussion is needed to clarify the relationship between child health and acoustic environment. When points of reference as well as decibel levels of common noise sources around us reported by "National Institute for Occupational Safety and Health" and acoustic conditions around the population established in medicine are considered, it is realized that children live in a terrifying acoustic environment, not perceived by the other members of the society. It is amazing to note that excessive noise sources are present in schools, hospitals, even, in neonatal intensive care units. It is necessary to realize the noise levels e.g. toys at the axis of child living. The common ambient noise sources, the auditory/non-auditory effects of noise on human health, individualistic/institutional problem-solving proposals will be introduced with its national/international dimensions supported by technical and medical facts as well as from clinical, pediatric, psychiatric, biochemical, social, economical, political, legal points of view.

Environmental conditions, rapid increase in birth rate, technological developments and economical difficulties affect the population from the psychosocial aspects. Children pass from fetal life into noisy urban environment, quite harmful for the organism. Children are a high risk group vulnerable to the effects of chronic noise exposure and may exhibit negative attitudes. Building a healthy acoustic environment during childhood will lead a population with social and psychological health.

A child, a developing and sensitive organism, is highly affected by the physical and chemical agents. More discussion will be needed on the relationship between acoustic environment and child's health.

Considering the reference values and noise levels reported by National Institute for Occupational Safety and Health, children live in a heavy acoustic environment, from neonatal intensive care units(NICUs) to hospitals; from child houses to schools; from toy sector to the field of industry. In children, chronic aircraft noise exposure impairs reading comprehension and long-term memory and may be associated with increased blood pressure.

Noise has potential harmful effects on newborn patients. It is an important health problem in NICUs. A continuous exposure to noise is a stress factor for premature infant. High noise levels may cause hearing-loss, and may vary physiologic and behavioral responses.

Newborn infants, particularly the premature ones, are affected by the noisy environment in NICUs. These units, supportive media for the child growth and development, are designed to meet the needs for the infant's physiology and neurobehavior.
criteria are going to support the permanent findings and favor the optimum sleep period needed for the infants.

Among the preventive measures taken for the reduction in noise levels, are decreasing the alarm sound to the minimal safety levels, examination and correction of the sound levels produced during the processing of the doors, use of the earmuffs, teaching the visitors and health care workers.

In the wards of a children hospital, maximum noise levels were reported around 60 dB, comparable with road-traffic noise, due to the frequent entrances and maximum visits.

Daily noise levels were detected as 80-85 dB in crowded public schools. Noise levels in corridors were decreased to 64 dB during the lecture-hours, as it may be increased to the levels of 95-98 dB during the breaks. It is quite interesting that noise levels observed in public schools come close to the critical values specified to protect hearing in adolescents. When the conditions were evaluated in secondary schools, daily noise levels affecting the school children during their school hours were found to be 73 dB. Noise exposure may show some variations in vocational schools. Machines are the major sources of noise in workshops. These levels can reach 90-100 dB in textile workshops and in wood craving machines.

This topic gains even further importance, since school children spend rather long periods in these acoustic environment. The critical value for the protection of hearing is accepted as 85 dB. These children have to work in an environment of 10-20 % above this value during their training. Considering the fact that the sensitivity is even higher in young individuals, this problem should be handled with great care in the workshops of vocational schools. This problem can be solved by shortening the working hours of the children depending on the noise levels.

In this context, the toy sector also gains importance. The hearing loss caused by the noise levels produced by toys is a great complication in the physical and mental development of the children. In some countries; despite the rules on the matter, the peak noise levels between 80-135 dB are still detected. As known, the noise levels above 85 dB within the time, the noise levels above 140 dB in a very short periods of time can give harm to the sense of hearing.

Noise levels and biochemical parameters may be closely related. Nervousness, irritability, high urinary excretion of cortisol levels and increased catecholamine secretion following the working hours of the day were reported as the symptoms related to the exposure to chronically high noise levels (>85 dB) in the industry. Considerable well-being in both psychological and physiologic stress reactions were reported when the noise levels were decreased. Also, cortisol levels were decreased and normal cortisol diurnal rhythm have been reached. Decreased working quality, increased blood pressure, increase in epinephrine, cAMP, magnesium, protein, cholesterol as well as decreases in serum vitamin C, erythrocyte sodium and renin levels were noted as the statistically significant reactions observed against noise.

Interactions between health and the environment were noted also by the politicians from time to time. Health problems expressed by the local population in relation to the environment were described. About 60 % of the population were complaining from noise as an environmental problem associated with health.

Noise is also a problem in law. For medical and legal problems met today, the legal requirements are still far from solving the daily problems. To prevent the confusions, first, the population should be made conscious about " In our advancing age, which sounds should be considered as normal and which should be as noise? ".

Today, some problems related to typical day-to-day noise exposure can be solved by the standardization in noise levels of the imported goods.

Traffic density will be prevented and thus, both air and noise pollutions will be avoided by the use of public transport vehicles.

Industry should be motivated to follow the strict guidelines. Products with low levels of noise should be manufactured. This will increase the quality of living and make a positive contribution to the prevention of noise pollution. A solution can be attained by reasonable preventive measures at the political level.

In conclusion, the world population is to live together with various negative environmental factors. Children constitute the age group mostly affected by environmental factors. Negative acoustic environmental conditions as well as air pollution are the leading environmental factors which affect children. Until we are conscious about the problem as the leaders and the population, we have to try to reach radical solutions with our attempts and tolerance. In this context, as a result of active environmental politics, technological developments proper for the acoustic environmental conditions should gain importance. Then, future populations will be able to catch the chance of living in a quiet environment far from noise.

REFERENCES


Risk Factor for Learning Process

S. Seballos a; P. Matamala b; L. Martínez c.

Universidad de Santiago de Chile(a); Hospital Clínico Fuerza aérea de Chile(b); Facultad de Ciencias Médicas(c)
Avenida Ecuador 3493(a) ; Avenida Las Condes 8631(b); Av. B. O” Higgins 3363 (c).
Santiago, Chile (a) (b) (c).
56-2-7763322(a) ; 56-2-7826078(b) ; 56-2-6819051(c)
56-2-7769596(a)  sseball1@lauca.usach.cl(a)

This work represents an improvement in the study of acoustic noise pollution that affects part of the Chilean school population (1,2). In the first part of the research project “Auditive diseases and acoustic pollution as risk factor for learning process” that we have analysed in about 200 clinical records of students. These data constitute a representative sample of the otolaryngologic health of 1413 children between 6 and 18 years old. The students have been selected by their teachers as potential patients because of hearing problems.(3) It was found the prevalence of hearing pathologies and learning disorders. By applying epidemiological analysis methods, “risk measurements” were elaborated as a function of the different risk factors or protectors. A cost – benefit analysis directed to the solution of these pathologies during the infancy is also presented.

INTRODUCTION

The Metropolitan Region of Chile covers more than 70% of students (schoolchildren) out of the total of the country, in its levels kindergarten, grade and secondary of that percent near 90% do it in education financed by the state, in schools distributed in all region.

The infrastructures of the establishments as well as the environmental conditions that surround them are extremely variable, but in a significant percent the conditions are precarious. Especially the quality of isolation related with environmental acoustic pollution.

Some establishment historically located in areas of a higher traffic or activities that emit noises above the general environmental norm, ruled in the Metropolitan Region for this pollution.

In the program of scholastic health “Junta Nacional de Auxilio Escolar y Beca” government agency that depends on the Ministry of Education, has estimated primarily a Prevalence of hearing problems of 3% in the scholastic population, considering pre-primary level up to middle level.

As it has been previously observed about 6.820 children in the year 2001, out of 227.326 will be suffering learning risk problems due to the above mentioned.

METHOD

From a universe of 21519 students between 6 and 10 years old, in the year 2000 a sample of N=666 was analysed through a screening of primary health in order to help define the quality of their hearing capacity. The size of the sample was determined according to resource availability and their teacher chose the selected students, some based on a specific agreed procedure and others based on the teacher’s observation of the prementioned students.

The technique used to determine the auditive threshold corresponds to classics audiometrics as applied to pure tones according to the American standard (ANSI). Quantitative psychosensorial measurement methods. (the results are tabulated numerically according to standardised graphs).

The tests were conducted by technologist and the diagnostics by otorhinolaryngologist.

RESULTS

The sample of 660 students submitted to the health primary screening selected 220 students with a hearing loss, this is equivalent to the 33.3% of the sample.

The tests given by otorhinolaryngologist show that deafness are due to the following causes:
1. Disease to the middle ear, with liquid accumulation in the tympanic layer, mucositis equivalent to 50.26% of the cases.
2. Disease to the inner ear with neurological sense hypoacusia, damage shows the need of a hearing aid in 14.66 % of the total cases.
3. A chronic infections disease to the middle ear (chronic medium otitis) which represents an 8.38 % of the total sample

The 220 classified cases correspond to an Incidence of a 33%. The students were included in the preventive health program.

In the year 2000, 255 students were controlled that presented hearing problems detected in the years previous to this research. Today the status of these students is the following.
1. Mucositis 44.4%
2. Sesorioneural hipoacusia 11.1%
3. Chronic middle otitis 20.23%
4. Patients in studies 24.21%

There exist a non-trivial number of students whose solution is through surgery.

CONCLUSIONS

The analyses of the obtained results allow concluding that the school population with severe hearing deficit is under a severe low learning risk.

Most students with a slight to a moderate deficit, (students with a tympanic mixiosis), also present a moderate risk that may become severe if the acoustic condition in their classrooms are not ideal.

This is a relevant point since tympanic mixiosis can be treated with a good prognostic, although there exits the inconvenience that many of them because of their not responding to medical treatment need surgical treatment of a relatively high cost performed by specialist.

This point is of the outmost importance given the learning curve by age a good hearing state is basic in the first grade school levels.

ACKNOWLEDGEMENTS

This research was partially supported by Universidad de Santiago de Chile. Dicyt.

REFERENCES

Disturbing Effects of Noise in Classroom of a Primary School

I. Čarič, M. Čudina

*a Primary School Spodnja Šiška, Gasilska 17, 1000 Ljubljana, Slovenia
*b Faculty of Mechanical Engineering, University of Ljubljana, Aškerčeva 6, 1000 Ljubljana, Slovenia

Noise in primary school is a highly disturbing factor influencing concentration, memorising, understanding of explanations and well being of children. It originates from the children activities or it enters from the surroundings as the result of traffic or of children playing at the school playground. Noise level was measured in different locations of the school and at different times, and than assessed with assistance of the opinion poll among pupils and teachers. The noise in the classroom depends on its position regarding streets and playground. Measurement results have shown that the level of the noise in the school, even, when there were no lessons, is over the limit or a little bit less. During the lessons the noise levels were much over the permissible level. Teachers are disturbed by noise at communication with their pupils and especially at work in the class, which demand a high level of concentration. Pupils can’t pull themselves together because of the noise, they can’t memorize the subject or they can’t understand the interpretation. However the opinion-poll have shown that younger pupils are more sensitive to noise then older ones. To reduce the annoying effects of noise in the school, several administrative and engineering measures were proposed.

INTRODUCTION

Noise is one of the most common sources of complaint in most of modern societies, frequently resulting in impaired hearing. In spite of the fact, that schools are one of the most prominent places for learning, very few detailed studies on the effects of noise on learning in schools were performed. Several studies have shown detrimental effects of noise on school achievement as for example reading ability [1-3], that increases with time of exposure. However, since these studies are correctional or cross-sectional, there is always a possibility that the uncontrollable characteristics influence the result in schools with high noise level. [4,5]

Due to complaints about the disturbing traffic noise around the Primary school Spodnja Šiška, a need for a control of the noise level appeared, especially due to a new building site in a neighborhood. For this purpose noise level was measured in different locations within the school and at different times, and than assessed with assistance of the opinion poll among pupils and teachers.

METHODS

The A-weighted equivalent noise level (L_{eq}) as well as maximum (L_{max}) and minimum (L_{min}) sound pressure level were measured by B&K sound level meter, Type 2260, in 15 different locations three times during the day at lessons, with windows open and closed. Another set of measurements was carried out in the "empty school". The measurement time was from 2 to 5 minutes. The opinion poll was performed among all pupils from third to eight class and among all teachers.

RESULTS AND DISCUSSION

The results of noise level measurements were presented in Fig 1 for empty school and in Fig. 2 during lessons. From Fig. 1 it is evident, that the noise level is slightly higher in the classrooms facing the street with heavier traffic and those facing the building site. As expected, the effect was much higher with open windows, while at closed windows the quality of windows showed beneficial effect.

![Figure 1](image-url)
FIGURE 2. Noise level in different locations during lessons with windows closed and open, measured at approximately 12:30; the line at 55 dB(A) indicates the permitted noise level; error bars indicate \( L_{\text{max}} \) and \( L_{\text{min}} \).

The highest value was measured during the lunchtime in the eating hall, where the \( L_{\text{eq}} \) was as high as 87.6 dB(A) with \( L_{\text{max}} 105.6 \text{ dB(A)} \). Even higher \( L_{\text{eq}} \) was obtained in gym hall, 92 dB(A).

According to the results of opinion-poll, the teachers are highly disturbed by noise at communication with their pupils and especially at work in a class, which demands a high level of concentration. Pupils can not pull themselves together because of the noise, they can not memorize the subject or they have difficulties understanding the interpretation; however the opinion-poll have shown that the younger pupils are more sensitive to noise then older ones.

In general, 67% of teachers and 50% younger pupils and 26% of older pupils are highly disturbed by the noise. There was no teacher not complaining about the noise, while 4% of younger and 14% of older pupils were not disturbed by noise at all. The opinion-poll has shown that the noise diminish their concentration (44%), reduce their short and long term memory (31%) and disturb their understanding of the teacher's interpretation (14%).

Almost equally pupils feel the disturbance from outside noise, i.e. traffic noise and building-site noise (44%) as well as noise from pupils themselves (47%).

It was interesting, that some pupils (7 to 16%) also feel uncomfortable in silence.

From Figure 3 we can see, that there is almost no pupil not being disturbed by noise, however, slightly increasing number signifies habituation to noise. Most of the pupils are moderately disturbed by the noise. Decreasing number of pupil expressing low noise tolerance could also be explained by habituation with exception of 6\textsuperscript{th} class where number of pupils in a class is much higher (29 instead of 22).

CONCLUSIONS

Results of the study have shown that the level of the noise in primary school was over the limit or a little bit less, even when there were no lessons. During the lessons the noise levels were much over the permitted level.

According to the results of questionnaires, teachers are disturbed by noise at communication with pupils and especially at work in a class, which demands a high level of concentration. Because of the noise pupils have difficulties concentrating, memorizing the subject or they have difficulties understanding the interpretation. Younger pupils are more sensitive to noise than older ones.

To reduce the annoying effects of noise in the school, several administrative and engineering measures were proposed in particular by window replacement, by changing of the traffic regime in the school surrounding as well as by some alternative measures, such as interal design, decoration, using special architectural elements, by equalizing forms and contents in paintings and sculpture, by means of color impression and forms (figurativity), by perspective which deepens the space, by synthetic music, which joins the sound, noise, electric tones with the tones of musical instruments and voice, etc., [6].

ACKNOWLEDGMENTS

The authors wish to thank Primary School Spodnja Šiška for permission and help with realization of the questionnaire and measurements as well as for the financial support.

REFERENCES

Efficiency vs. Acceptability of Hearing Protectors in Industrial Environments

P. M. Arezes and A. S. Miguel

Human Engineering Group, DPS, University of Minho, 4800-058 Guimaraes, Portugal

Although hearing protectors must be used as a temporary solution, their choice should take into account several aspects, such as ergonomics features associated with this kind of device. The present study aims to analyse the relationship between the acoustical attenuation efficiency and other aspects related to the comfort afforded by hearing protectors, and consequently their acceptability, when used in industrial noisy environments. A comfort evaluation was performed using a questionnaire, filled by 20 workers. Several scales related to the subjective feeling of comfort were used to quantify the comfort index of a given protector. Simultaneously, the wearing time of each protector was self-recorded by each subject. To test the relationship between the comfort index and the time during which protectors were used, it was applied a variance analysis (ANOVA). Results obtained seem to demonstrate there are significant differences between catalogued and effective attenuation. Protectors with less catalogued attenuation, but with higher acceptability, i.e., more comfortable, tend to be more efficient than protectors with higher catalogued attenuation, but less comfortable. Finally, it must be emphasised that high efficiency can only be achieved through the attainment of an adequate balance between the range of parameters likely to determine its usage.

INTRODUCTION

Portuguese legislation concerning worker’s protection against occupational noise (D.L. 72/92 and D.R. n.º 9/92) [7], which transposes the European Directive no. 86/188/CEE, of 12th May, emphasizes that priority should be given to intervention actions which focus either on reducing noise levels as close as possible to their source or on acting upon noise propagation fields.

Despite the importance and efficiency assigned to the former intervention measures, individual hearing protection is also useful despite being regarded as a last resource as far as protection against exposure to noise is concerned. The selection of hearing protection shouldn’t be exclusively determined by the acoustical attenuation characteristics of the device [1]. Other, equally important, ergonomics features associated with this kind of protective device must be taken into account. Illustrative examples of the former include comfort, the need for verbal communication or auditory signal detection, compatibility with other safety equipment, durability, maintenance, to name a few. The present study focused on evaluating some HPD in industrial environment and on comparing real efficiency against the predict one.

METHODOLOGY

Comfort Evaluation

A comfort evaluation was performed using a questionnaire, which was filled in by 20 workers of 2 industrial companies, whose workplaces presented noise pressure levels higher than the Portuguese threshold value for daily occupational exposure (L_{AP,d} > 90 dB(A)).

RESULTS AND STATISTICAL ANALYSIS

Comfort Index (CI) Composition

To compose the Comfort Index (CI) only some scales were used. Because “comfort” was the hypothetical construct of major interest, any scale achieving a high correlation with the “comfortable-uncomfortable” is likely to influence the subject's perception of global
Comfort Index/Time in Use relation

Within the scope of this study, an analysis was undertaken into the relation between the Comfort Index and Time in Use (TU), expressed in minutes per week. The main objective of such analysis is to determine whether the tested group or HPD variables have any influence in the values of CI or TU. A two-way analysis of variance (Two Way ANOVA) was applied for this purpose and the following results have been obtained:

- There is significant evidence of variation in the CI, either with the tested group or with the HPD.
- There is also significant evidence of variation in the TU, either with the tested group or with the HPD.

CONCLUSIONS

On the basis of the study developed and obtained results, the following conclusions can be drawn:

- There are no significant differences in the comfort sensation between the same type of HPD. In other words, CI values obtained only differ when comparing earplugs and earmuffs. No differences have been found between the different types of earplugs or earmuffs.

- It is statistically significant the positive correlation between CI and TU, i.e., HPD with higher CI values also have higher TU values, and vice versa.

- There are substantial differences between nominal, or catalogued, attenuation and effective attenuation, or real attenuation. Greater effectiveness in attenuation is ensured not by those HPD with the highest nominal attenuation, but by those with the highest CI values. This feature is more evident for earmuffs.

- Comfort, or the subjective comfort feeling, while being a possible quantifying parameter, is undermined by the fact that this is dependent upon a wide range of factors, such as those referring to the environmental characteristics of the workplace, namely the acoustical and thermal environments. In addition, the comfort sensation is also influenced by other non-acoustic parameters, such as its appearance or its physical configuration.

The selection of HPD must, whenever possible, be made both by workers, managers and staff from the Health and Safety department. The variety of HPD currently available, namely with respect to sizes and configurations, is enough to allow the workers a more personalized and adequate choice which, in turn, will improve significantly their compliance with the obligation of usage of hearing protection.

Finally, and given the main goal of HPD, namely that of effectively attenuating sound pressure levels, we must emphasize that the former goal can only be achieved through the attainment of an adequate balance between the range of parameters likely to determine HPD usage. Moreover, we must not neglect the role played by the workers themselves for their attitude towards the use of hearing protection will ultimately determine the overall success of any hearing conservation program. At this respect it is extremely important that adequate attention is diverted, from all organizational levels, to issues relating to workers training and education regarding Health and Safety matters in general, and hearing protection and conservation in particular.

REFERENCES


7. Decreto-Lei nº 72/92 de 28 de Abril, "Protección dos trabalhadores contra os riscos devidos à exposição ao ruído durante o trabalho", and Decreto Regulamentar nº 9/92 de 28 de Abril.


Acoustic Plans of Towns and Urban Areas
-Selected Problems

A. Izewska, M.Niemas, J. Sadowski

Department of Acoustics, Building Research Institute, Ksawerow Str.21, 02656 Warsaw, Poland

In the past thirty years a lot of the acoustic plans of towns and urban areas have been worked out in many countries. Various methods of preparing acoustical plans, which take into account the different acoustical parameters, have been used. Some problems with applying acoustic plans for environmental noise protection and town planning have arisen. This paper systematizes the preparation methods of noise maps and shows the need for the unification of the methods of preparing the noise maps.

THE AIM OF PREPARING NOISE MAPS

The main goals of noise maps are as follows:

- identifying the scale of noise problems at the local, regional or national level,
- setting the objectives for noise reduction in a certain area, taking into account the existing or the projected situation,
- monitoring the effectiveness of the plans designed for noise reduction (changes in the traffic planning, land planning, reduction of sound transmission by using the noise barriers, abatement by sound insulation measures, control of noise sources etc.),
- presentation of the noise-related data to the citizen.

At present, these goals can be met through a variety of forms of presentation, using the different calculation and/or measurement methods for different noise parameters. Many countries have their own methods. In Poland, the first noise maps of towns were prepared in the years 1968 –1970 [1], and the map of Poland, with specification of the areas and the numbers of people exposed to noise – in the year 1989. Until the year 2000, noise maps were prepared for over 200 towns.

SYSTEMATICS OF THE NOISE MAPS

General Classification Due to Environmental Noise Sources

Noise maps can be prepared for all the noise sources that occur within the given area (synthetic maps) or for the selected type: road traffic source, railway traffic source, air traffic source and industrial source (analytical maps). Synthetic maps convey information on the general environmental condition and are used mainly for noise estimates from the point of view of protecting the health of the people. Analytical maps convey information on the scope of the impact of the respective types of noise. This makes them useful not only for information purposes, but also at the designing of the acoustic protection and at making prediction for the environment. The synthetic and the analytical maps are prepared for areas of different capacity and purpose, with the use of various kinds of parameters determined with the use of measurements and/or calculations.

Classification Due to the Capacity and Purpose of the Area

Due to area capacity, noise maps can be divided into the following groups: 1) maps of the areas adjacent to noise sources such as roads, railway lines, airports or industrial plants, 2) maps of towns or parts thereof, 3) maps of regions, 4) maps of the whole country. The selection of the scale depends on the purpose for which the map is being prepared (zoning or planning of acoustical protection) and on the level of the complexity of the acoustic problems within the given area.

Classification Due to Acoustic Parameters and the Methods of Their Determination

The basic parameter used for noise mapping and acoustical planning is the equivalent continuous A-weighted sound pressure level for a specified time interval \( T \), \( L_{Aeq,T} \). In general, \( T \) is a day (16 hours) and a night (8 hours). However, the noise level changes depending on the day of the week or of the season of the year. Therefore, in order to describe the noise in the best possible way, one should take into account the long-term interval, which can last a week, a month, a number of months or a year. Apart from these, one can also apply other directly related parameters, namely: percentile level \( L_{AN,T} \) (the level \( L_{Aeq,T} \) that is exceeded for \( N \)% of time \( T \)) and \( \Delta L_{Aeq,T} \) (exceeding of the noise level \( L_{Aeq,T} \) within the given area). The last parameter is used in order to indicate the areas in which actions for the improvement of the environment must be taken (conflict maps). In the project of the EC Directive [2], there is a proposal of using two noise indicators - \( L_{den} \) and \( L_{night} \). The values of these noise indicators in front of dwellings, combined with the
dose-effect relations, would have to serve for predicting the average response of a population in terms of annoyance and sleep disturbance. Dose-effect relations should be determined on the basis of surveys. Standard procedures for conducting such surveys are the subject of the working group ISO/TC43/SC1/WG 49. A considerable number of such surveys has already been carried out (also in Poland [3,4]). However, the adoption of common dose-effect relation for all the countries might pose difficulties due to the influence of psycho-physical and psychological factors on the noise perception, different for various countries.

The values of noise indicators can be determined either by measurement or by computation. The principles for long-term average measurements are presented in ISO 1996-2:1987. There are also other ISO standards, national standards and commonly acknowledged documents which refer to the methods of measuring the respective types of noise: road traffic noise, railway traffic noise, air traffic noise and industrial noise.

It is recommended to take into account the influence of meteorological factors. Noise maps, prepared on the basis of measurements, should be prepared for the same season of the year and for similar meteorological conditions defined within a specified scope. In case of calculation methods, the used software should take into account this influence. An example of solution to this problem is the method developed in France and applied in the „MITRHA” program prepared by the CSTB. Presently, in preparation at the Acoustics Department of the ITB is the new versions of the instructions of ITB regarding the preparation of noise maps, into which the „MITRHA” program shall be included.

Other parameters used for the preparation of noise maps for the general estimation of the environmental condition are the global indicators: the percent of people that is affected in a certain noise polluted terrain (%AP) and the percent of the area’s surface over which the maximum noise threshold level is exceeded (%AT).

An example of these are the acoustic maps of Poland, prepared in Poland in the years 1989-1990 by the ITB, which present the location of the parameters specified above, categorized according to 4 degrees of pollution [fig.1].

CONCLUDING REMARKS

In Autumn 2000, the European Commission prepared a proposal of a Directive dealing with the principles of preparing noise maps. The Directive included a number of arrangements for the unification of measurements and calculations. Still, there seems to be every reason for starting a wide discussion on that subject. Among its subjects should be both the recommended indicators and their practicability for the set goals (including the estimation of the impact of noise on people's health and well-being). Important question is: in case of characterizing the annoyance of noise, shall the proposed indicators $L_{den}$ and $L_{night}$ be sufficient? Is there a need for the introduction of additional indicators which would characterize short-term noise of high level? The past experiences of the Acoustics Department of the ITB has shown that subjective evaluation of annoyance of noise is dependent not only on the time average level of sound $A$, but primarily on its maximum value (especially for the night time).

The applied ambient noise indicators should be confronted with their usefulness for the estimation of noise impact on people's health and well-being. Within this scope in Poland, in the years 1973 – 2000, we have conducted researches whose results could be used [3,4]. There is a need for initiating a discussion on formulating the appropriate method of dose-effect relation, or - at least - for establishing a common way of addressing this problems at the preparation of noise maps for the needs of the EU Environmental Protection Committee.

REFERENCES

Due to industrial plant customer’s awareness and legislator’s attention about aspects connected with environmental noise, engineering companies developing new settlements are often required to design in order to respect also noise limitations in terms of maximum allowed sound power level. This vision represents a new approach to industrial plants design: it requires to the plant constructor to supply low noise equipment and noise reduction systems in order to comply with the goal. Presently noise predictions using sound power levels are more articulated than those provided by means of sound pressure levels for lack of manufacturers data and because plant customers and equipment suppliers usually deal with pressure levels, easier to be measured.

INTRODUCTION

Noise allocation assessment has become an important design parameter for new industrial plants. The engineering companies are now more and more frequently requested the acoustical project relevant to industrial plants to be developed starting from the allowable maximum sound power level related to the whole plant. To predict environmental acoustical impact, here is highlighted in which way, starting from the sound power level, it is possible to verify the noise limits values established by the Authorities, generally expressed in terms of sound pressure levels. Vice versa, starting from an averaged sound pressure level contour, it is possible to go back at the total sound power level due to all sources generating the sound field.

NOISE LIMITS

In order to plan a noise reduction program for new industrial plants, it is necessary to establish noise limits to comply with. There are as many noise limits, according to as many criteria, distinct on application areas, exposed or interested subjects, type of noise source besides the enforcing subject, mainly the authority and the customer. Used noise limits to design industrial plants are generally expressed as sound pressure level and apply to the followings: - equipment, to limit workers exposure or identify restricted areas, where noise reduction is not reasonably practicable and ear protection must be worn; - emergency devices, such as alarms or discharges; - background noise inside occupied buildings, in terms of Noise Rating (NR) or Noise Criteria (NC) curves, to ensure no interference with work, communication and concentration; - property fence, surrounding area and receiving points, to respect environment and community. Based on the above-mentioned noise limits and following a preliminary noise impact study, further noise limits in terms of sound power level can be defined for the whole plant or its areas. Allowed maximum sound power levels can be then evaluated through noise simulation models; an example is given by the following formula, proposed by Stüber and reported in the ISO 8297 standard[1]:

\[ L_{ew} = L_p + 10 \log (2S_m + hl) + 0.5\alpha \sqrt{S_m} \] (1)

where, for a given iso-level or enveloping contour, \( L_p \) is the average sound pressure level along it, \( S_m \) is the delimited area, \( h \) is the receiver height above the ground, \( l \) is the contour perimeter and \( \alpha \) is the air absorption coefficient.

For plant design purpose, sound power levels are handier than sound pressure levels, due to their invariability with surrounding space. The established sound power level limits and the noise allocation allow checking acoustic plant conformity and carrying intervention adjustments during each design stages.
NOISE ALLOCATION

To develop the noise allocation, it is required the design documentation including plant layouts, equipment list, installed electric power list, equipment manufacturers noise information. Working on these data, the assessment study and the acoustic planning can be worked out through three steps, evaluation, design and check.

In-plant and environmental noise assessment without mitigation systems

The most important element for carry out the acoustic study is represented by equipment noise data. Generally sound power level spectra are not available, even if vendors are requested to provide them. For this reason the initial evaluation is made using equipment noise data taken from historical data base, international standards and directives, theoretic or practice formulas. Plant acoustic situation without noise reduction systems is then assessed considering sources grouped by productive sections, so that critical areas are evident at once. The analysis results are represented in noise maps and summarised in a table (see Table 1.).

Noise abatement design

Sound proofing interventions on significant noise sources are foreseen in order not to exceed the overall plant sound power level (see [3]), accordingly to layout, process and safety need. The preferred solution is to reduce noise emissions at source, by means the following intervention:
- for equipment, by supplying low noise type items (eventually designed after ISO guide lines[2]), by noise hooding (to be avoided for machinery handling flammable substances) or, lastly, by enclosing in buildings;
- for valves and piping, by coating with sound deadening materials and by inserting duct silencers at blower inlet and outlet;
- for vents, by installing adequate silencers;
- for buildings containing noisy equipment, by improving sound insulation of walls, external doors, windows, louvers; taking into account ventilation, safety, maintenance and cleaning requirements;
- for Heating, Ventilation, Air Conditioning systems (HVAC), by providing low noise type fans and by duct silencing.
Where not possible to act on the noise sources, suitable acoustic screens can be installed near them.

<table>
<thead>
<tr>
<th>Plant Area</th>
<th>$L_{Ww}$ before dB(A)</th>
<th>Sound Proofing System</th>
<th>$L_{Ww}$ after dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop reactors</td>
<td>105</td>
<td>LN, NH, EB</td>
<td>103</td>
</tr>
<tr>
<td>Gas phase reactors</td>
<td>115</td>
<td>NH</td>
<td>107</td>
</tr>
<tr>
<td>Recoveries</td>
<td>110</td>
<td>NH</td>
<td>103</td>
</tr>
<tr>
<td>Purification</td>
<td>105</td>
<td>NH</td>
<td>100</td>
</tr>
<tr>
<td>Ethylene compressors</td>
<td>112</td>
<td>EB</td>
<td>106</td>
</tr>
<tr>
<td>Utility</td>
<td>100</td>
<td>LN</td>
<td>100</td>
</tr>
<tr>
<td>Pelletising</td>
<td>109</td>
<td>WAI, DS</td>
<td>100</td>
</tr>
<tr>
<td>Powder bins</td>
<td>122</td>
<td>PAI, DS</td>
<td>113</td>
</tr>
<tr>
<td>Blending</td>
<td>119</td>
<td>PAI, DS</td>
<td>110</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>125</strong></td>
<td><strong>-</strong></td>
<td><strong>117</strong></td>
</tr>
</tbody>
</table>

* LN = equipment Low Noise type, NH = equipment with Noise Hood, EB = equipment Enclosing in Building, WAI = building Walls Acoustic Improvement, PAI = Piping Acoustic Insulation, DS = Duct Silencers for blowers and HVAC

Besides technical aspects, the economic impact of noise reduction plan on plant cost should be considered. As result, one obtains the noise allocation with sound proofing systems (as shown in Table 1.).

CONCLUSIONS

According to the proposed paper, the compliance with sound pressure levels fixed by the Authorities can be obtained, with best and adequate accuracy, by transforming them in sound power level values. Moreover, sound power levels are influenced neither by other noise sources nor by environmental conditions therefore, starting from the sound power emitted from the whole plant, one is in a position to know the sound pressure distribution throughout. This work has tentatively looked up trace out a guideline to face the subject matter.

REFERENCES

Geographic Information Systems (GIS) for the Monitoring of the Messina Environmental Noise

G. Bellissimo\textsuperscript{a}, G. Cannistraro\textsuperscript{a}, C. Giaconia\textsuperscript{b} and A. Piccolo\textsuperscript{a}

\textsuperscript{a}Department of Physics, Messina University, 98166 Messina, Italy
\textsuperscript{b}Department of Energetics and Physical Applications, Palermo University, 90100 Palermo, Italy

In the present work Geographic Information systems (GIS) have been employed to create noise maps of Messina on the basis of measurements collected in the urban area of Messina. The maps allow to get information on the impact of the new tramway on the acoustic climate of Messina.

INTRODUCTION

Environmental noise, caused by traffic, industries and infrastructure in general, is one of the main local environmental problems of modern life, especially in residential areas. Policies on noise control have been developed in most European countries and noise effect studies are now intensively carried out to support these policies. An important issue is to monitor the effects of existing infrastructure and to study the possible effects on the environment when a new infrastructure is planned. These effect studies support the decision-making process. Based on these studies, the design with the least environmental impact can be selected and measures can be devised by which further environmental impact is reduced.

In this frame, in the present work an investigation on the impact that the construction of the new tramway induces on the acoustic climate of Messina is reported. At this stage a preliminary noise map elaborated with the aid of a GIS software package is presented.

GIS AND NOISE MAPPING

To successfully implement noise control measures, it is first necessary to obtain information about the noise levels to which people are exposed, i.e., to make a noise assessment.

Powerful noise assessment studies are possible by integration of Geographical Information Systems (GIS) and noise mapping.

In the strictest sense, a GIS is a computer-based tool capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations [1].

The key word to this technology, in fact, is Geography - this usually means that the data (or at least some proportion of the data) is spatial, in other words, data that is in some way referenced to locations on the earth. Coupled with this data is usually data known as attribute data. Attribute data generally defined as additional information, which can then be tied to spatial data. It is the partnership of these two data types that enables GIS to be such an effective problem solving tool. GIS operates on many levels. On the most basic level, GIS is used as computer cartography. However, the storage of data in an easily accessible digital format allows not only paper maps be produced far quicker and more efficiently. The real power in GIS is through integrating common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. The end result of the analysis can be derivative information, interpolated information or prioritized information.

Noise mapping is the representation of acoustic data in a cartographical format - similar to that employed when plotting height contours on a conventional land map. Its benefits are the visualization of acoustic data.

By combination of the information with a geographical information system (GIS) enabling the correlation of different datasets.

Moreover, the use of modelling based on complex propagation algorithms, allows to predict noise data and, so, to analyze various scenarios with respect to noise before an actual implementation can completely eliminate the need for trial and error and, consequently, reduce expenses significantly.

In synthesis, noise maps in conjunction with GIS are an essential tool for anyone involved in the process of planning the building or revision of airports, industrial plants, railways, ports, roads, etc.
RESULTS AND DISCUSSION

In the present work a preliminary noise effect study on the city of Messina has been carried out by a GIS software package. A noise map has been created for immediate visualization of acoustic data.

This noise map is shown in Figure 1. Bars represent measured average daily values (6:00-22:00) of the $L_{eq}(A)$ parameter relative to sites located in the urban area crossed by the new tramway. Measurements have been made by a class-I phonometer in conformity with the current normative.

These data, integrating the existing acoustic database created in 1992 [2], constitute an input for the GIS by which is possible making analysis for:

- monitoring the current noise situation;
- evaluating the impact of new tramway on the urban acoustic climate;
- comparing exposure levels of the population with limit levels fixed by normative [3];
- to have information about the applicability of noise prevision models.

Since noise policies rely on the results of noise studies, the proposed analysis can be useful to the local administrations for elaborating action plans (compatible with the new infrastructure) intended to reduce the noise generated by the road traffic.

REFERENCES


Sustainable airport development: Evaluating non-acoustical noise abatement procedures

J. Vogt, E. Haugg and M. Kastner

Department 14, Organizational Psychology, University of Dortmund, 44221 Dortmund, Germany, vogt@orgapsy.uni-dortmund.de

60 residents at Düsseldorf International, 120 at Dortmund and 45 at Augsburg Regional Airport were investigated with respect to annoyance, their attitudes towards the airport, their ambitions for good neighbourhood etc. An open, personal and honest way of information exchange was the most mentioned desire of the residents. It was addressed at least equally often than physical abatement procedures. In an attempt to facilitate this information exchange, a noise telephone for Dortmund Regional Airport was installed. It was used only by few people, but these assessed it very positive. Early morning and late evening noise events were reported to be most disturbing. In order to take measures against this, Augsburg Regional Airport plans to limit the frequent evening helicopter flights to 7 p.m. The benefits of this measure will be subjected to further study.

INTRODUCTION

Already in the first Heathrow study [1] it was concluded that attitudes towards aviation in general and noise in particular significantly affect annoyance. People, who think that too little is done against noise, who are afraid of accidents and fear for their health are more annoyed than people with neutral or positive attitudes under the same noise load ([1], p. 77). Negative emotions like fear and anger are especially induced when people are kept in suspense and future developments are beyond their influence.

Therefore, the information exchange between noise producers and people annoyed plays an important role in noise control policy. A study about neighbourhood noise in The Netherlands showed that in 40 % of the cases a dialogue took place, which in 60 % could at least partially resolve the noise problem [2].

However, only few noise producers and authorities consider an open information policy as annoyance abatement procedure. An example is John Wayne Regional Airport in California [3]. The local noise abatement committee maintains a continuous information flow between pilots, airlines, airport and representatives of the residents. In a quarterly report the committee negotiations are published. Moreover, the airport informs the public about noise abatement procedures e.g. operational incentives for low-emission aircraft.

The following study investigated noise annoyance, attitudes towards the airport, the role of information policy and their mutual influences. A personal and online way of information exchange (mobile noise phone) was developed and offered to residents at Dortmund Regional Airport. In a follow-up study, the noise phone was evaluated and in a replication it will be installed at Augsburg Regional Airport.

METHOD

From February to July 1998, 60 residents at Düsseldorf International and 120 at Dortmund Regional Airport were interviewed (90 minutes on average). Most of them also volunteered for three blood pressure measurements and a saliva sample. The latter was used to determine immunoglobulin A (IgA) via radial immune diffusion technique. In an ongoing study, 45 residents at Augsburg Regional Airport were interviewed (40 minutes on average) and 55 are to follow.

The interview combined standardised ratings about e.g. annoyance and activity interference with half-structured questions concerning attitudes towards the noise producer and desired counter-measures. Only in Düsseldorf and Dortmund, data about family history of cardiovascular diseases, smoking, physical activity, diet etc. were obtained to control for the physiological measurements.

Workday Leq values were known for the Düsseldorf (50 to 70 dB(A)) and Augsburg investigation areas (40 to 55 dB(A)). In Dortmund, measurements were conducted and revealed 40 to 58 dB(A).

In the interview, people were also asked whether they would participate in a development process with the airport. 70 to 90 % of the residents wished a personal mode of information exchange (noise telephone, round tables). Among the 120 Dortmund subjects, 85 agreed to use a future noise telephone
operated by the University (positives). Only 12 of the 85 people really did (participants), 35 did not see the necessity of a noise telephone (negatives). A 24-hour, toll-free mobile phone was installed for Dortmund Airport during March and April 1999. It was operated by final year psychology students, who were well informed about aviation in general and the Dortmund noise situation in particular. They recorded complaints, gave information to the residents and feedback to the airport. In order to evaluate the effects of the noise telephone, 8 of the 12 participants, 9 negatives and 26 positives were investigated a second time from May to June 1999. This noise telephone will be installed for Augsburg in July and August 2001.

RESULTS

It was already reported in [4] and [5] that neither between Düsseldorf and Dortmund nor within the investigation areas at one airport significant differences occurred with respect to blood pressure or IgA. However, as could be expected, mean annoyance on a seven point category scale was significantly higher in Düsseldorf (4.7±1.7 mean ± standard deviation) compared to Dortmund and Augsburg (3.8±1.6 and 4.0±1.5, p<.001 and .025 respectively).

Especially bothering on the acoustical side was nocturnal and early morning noise (mentioned by 25 to 32% of subjects). Intensive single noise events were mentioned in Düsseldorf as well as Dortmund (10%) and the helicopters in Augsburg (25%). The main other source of annoyance was the information policy of the airport, which was perceived by the residents as “non-transparent” or even “unhonest”. At all three airports, there was a great desire for an open and honest information policy (Tab. 1). Physical noise abatement procedures like “freeze status quo” and “reduce noise” were not mentioned more often.

<table>
<thead>
<tr>
<th>Table 1. What do you want the airport to do? Percentages of answers</th>
<th>Düsseldorf</th>
<th>Dortmund</th>
<th>Augsburg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise reduction</td>
<td>13</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Freeze status quo</td>
<td>21</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Honest, reliable information policy</td>
<td>30</td>
<td>30</td>
<td>48</td>
</tr>
</tbody>
</table>

Probably due to the rather low noise level around Dortmund airport, the noise telephone was only rarely used. 27 calls from 12 subjects were recorded. However, those who used the phone assessed it very useful (mean ± standard deviation on a five point category scale 4.6±0.7, p<.001 against centre of scale).

In some cases, anger and fear were due to mal-information and could easily be resolved. Precipitation on leaves for example was quite often believed to be generated by regular fuel-dumping of approaching aircraft. The simple information that the most common aircraft in Dortmund, the ATR42 and ATR70, have no fuel-dumping facility, resolved the negative emotions. The information service of the telephone operators was rated good (4.3±0.8 on a five point category scale, p<.001). However, mean annoyance before and after introduction of the noise telephone was not different for neither of the three groups.

CONCLUSIONS

Active and passive noise control as well as procedural abatement certainly remain the most important protection measures. However, in order to achieve a good neighbourhood, an open and bilateral information flow should be initiated and maintained. As described above, media can be for example round table discussions, noise abatement committees or online facilities via internet or telephone. Much of the emotional (and potentially health impairing) stress, which can be observed in the interaction of air-service providers and residents - especially when airport extensions are licensed - could probably be prevented by an open and constructive dialogue.

ACKNOWLEDGEMENTS

The Augsburg study is kindly supported by a grant of the Flughafen Frankfurt Main Stiftung.

REFERENCES

Economic Assessment of Traffic Noise Impacts

M. Chahine¹ and M. El-Fadel²

Department of Civil & Environmental Engineering, American University of Beirut
Bliss Street, Post Office Box 11-0236, Beirut, Lebanon
¹ Research Assistant, mchahin@cyberia.net.lb
² Associate Professor, mfadel@aub.edu.lb

This paper presents an economic impact assessment of noise impacts from vehicular traffic on communities in the Greater Beirut Area (GBA). Field noise measurements were collected at selected locations in the GBA. An economic valuation of noise-impacted areas was performed using home rental statistics, noise measurements, and population affected.

INTRODUCTION

Elevated noise levels have been associated with adverse impacts on human health. These impacts can range from minor annoyance to physiological damage. Noise pollution can cause sleep disruption, speech interference, and inability of individuals to enjoy leisure time, thus impairing their quality of life. It can also cause anti-social behavior, and can lead to chronic stress resulting in many secondary problems such as the association with a reduction in children’s learning skills. Based on noise measurements conducted at different locations an economic valuation of noise impacts was then performed using a hedonic approach. Finally, mitigation measures are outlined for proper management of vehicular noise in urban areas.

NOISE MEASUREMENTS

Noise measurements were recorded in December 1999 and April 2000 during the morning, evening, and night times using an integrating sound level meter type 2800 with a microphone model QE7052 manufactured by Quest Technologies. The meter was held at 1.5 meters above ground level for a fifteen-minute period. The meter records the sound pressure level (SPL) in decibels and was set at the A-weighting filter system, hence measurements were recorded in dBA.

The study area includes the overall GBA, which was subdivided into 6 zones (Figure 1). The regions were subdivided according to their geographical location and to the activity conducted within their boundaries. Zone A is mainly a residential and commercial area while zones B and C are residential and commercial areas with a vibrant night life. Zones D and E are mainly residential areas with very light commercial activity while zone F is a heavily populated residential and commercial area.

Average recorded noise levels for each zone and period of the day are depicted in Figure 2. Noise levels are very comparable in the six areas, except for zones B and C, which showed higher levels during the night time due to nightlife activities in these neighborhoods. The noise levels exceeded the recommended levels set by the Federal Highway Administration Noise Abatement Criteria (FHWA NAC) level of 72 dBA except at some locations for the evening time in zone C. In addition, noise levels recorded during the night exceeded the recommended levels set by the WHO (World Health Organization). According to the WHO, noise levels should not exceed 55 dBA in outdoor residential areas during the night [1].
ECONOMIC VALUATION

Noise is best known for its disruptive effect as it can cause loss of sleep, decrease in productivity, and loss of hearing. These effects are very hard to quantify in monetary terms. However, since noise is associated with a place, its social cost has been commonly related to a loss in property value [2]. In this context, the hedonic price method has been extensively used to evaluate social cost due to noise pollution from vehicular traffic. While hedonic methods have become the best-suited techniques for estimating the noise damage cost [3], they require much hard to get data to conduct a meaningful cost estimation. Another method for the evaluation of noise cost is through the determination of the Willingness to Pay (WTP) for environmental benefits. This method consists of asking people if they are willing to pay for a reduction of noise in their neighborhood for example [4].

Hedonic Price Method

The cost of noise can be best estimated by the decline in a property value affected by noise generated from vehicular traffic [5]. Most estimates are developed using hedonic pricing methods which assume that an item’s value (property or house) is composed of a number of factors (area, age, location, neighborhood, environmental quality, etc.). To have a valid estimation of the noise cost using the hedonic price method, data such as noise levels, population and properties values is essential. The decline in the price of a property can be modeled as a function of ambient noise [6], for this purpose a Noise Depreciation Index or the percent reduction in a house price per dBA above a reference background value is used. Using this method, the annual cost of noise impacts can be estimated from Equation 1:

\[ C = NDI \times R \times (N - N_0) \times H \]  

Where  
\( NDI \) = Noise Depreciation Index  
\( R \) = annual average house rent  
\( N \) = noise level  
\( N_0 \) = background noise (55 dBA)  
\( H \) = number of residences

Cost Estimation

Research has shown that the NDI value ranges from 0.2 to 0.6 percent and a background noise of 55 dBA is typical in urban areas [5]. The number of residences and annual rent was adjusted for the year 2000 based on a household survey conducted in 1994 (Table 1) [7]. The average annual rent was adjusted for an average house lifetime of 30 years and a mortgage interest of 6 percent. The average noise level of the three periods (morning, evening, and night) was adopted. The corresponding total social cost due to vehicular traffic noise was estimated at 191.7 millions USD per year or 766 USD per household per year.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Annual Rent (USD)</th>
<th>Noise (dBA)</th>
<th>Residences</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5,090</td>
<td>72.6</td>
<td>57,966</td>
</tr>
<tr>
<td>B</td>
<td>11,125</td>
<td>79.7</td>
<td>27,048</td>
</tr>
<tr>
<td>C</td>
<td>18,150</td>
<td>74.2</td>
<td>75,122</td>
</tr>
<tr>
<td>D</td>
<td>7,270</td>
<td>71.0</td>
<td>12,785</td>
</tr>
<tr>
<td>E</td>
<td>10,890</td>
<td>74.9</td>
<td>18,745</td>
</tr>
<tr>
<td>F</td>
<td>3,630</td>
<td>72.6</td>
<td>55,523</td>
</tr>
</tbody>
</table>

LIMITATIONS

A limited number of measurements were conducted at major intersections only, which might overestimate noise exposure levels thus increasing the social cost caused by traffic noise. In addition, the social cost was calculated assuming a uniform average noise level in the six zones. Accordingly, more measurements may be required to be conducted at different types of roads (highways, principle and minor arterial, etc.), and the social cost calculation would be based on these measurements along with the number of residences near each type of road.

REFERENCES

Noise Reduction in a Car Cabin using Microphone Antenna Arrays
Leonid Krasny

Ericsson Inc., 7001 Development Drive, RTP, NC 27709, USA

This paper presents a novel array processing algorithm for noise reduction in a hands free car environment. The algorithm incorporates the spatial properties of the sound field in a car cabin and a constraint on allowable speech signal distortion. The experiments indicate that the proposed algorithm gives substantial performance improvement of 15-20 dB in comparison with the conventional array processing which is based on a free-field sound propagation model.

INTRODUCTION

In a car environment, the speech signal is often corrupted by background noise, which degrades the performance of the coding and recognition algorithms. It is essential to reduce the noise level without distorting the original speech signal. Two conventional approaches have been developed to solve this problem. One is a single microphone noise reduction technique, which utilizes differences in the spectral characteristics of the speech signal and the background noise. It is hampered by the fact that in many situations the speech and the noise tend to have similar spectral distributions. Under these conditions, the single-microphone noise reduction technique will not yield substantial improvement in speech intelligibility. On the other hand, the signal and the noise in a car cabin are acoustical fields, which have different spatial characteristics. This is the basis of the second approach, which exploits the spatial separation of the speech signal and the car noise.

It is known that spatial signal processing requires antenna arrays that combine the outputs of several microphones. Received signals are filtered at each element of the receiving antenna array and are summed up to produce an output signal. Noise components in the received signals are reduced in these filters. The determination of the frequency responses of the filters at the elements of the receiving antenna is the major area of concern in array processing, and a considerable amount of effort has been spent in this area [1]-[2]. However, there exist some difficulties, which become apparent when the conventional array processing technique is applied to noise reduction in a car environment. The problem is that the conventional approach is based on an assumption that the sound is radiated into open space and there are no obstacles opposing its free flow outward. This model is clearly unrealistic for a car environment, where sound generators are in an enclosure small enough so that the waves produced are reflected back and forth many times a second. Therefore, the effects of waveguide sound propagation should be taken into account for synthesis of the practical noise reduction system.

In this paper a novel array processing algorithm for noise reduction in a hands free car environment is proposed. The algorithm provides a matched-field array processing which exploits both spatial and temporal information of the signal and noise fields in a car cabin.

SIGNAL AND NOISE MODELS

We assume that the speech generator (talker) is a simple point source with the spatial coordinates $r_0$. Then, the signal spectrum $S(\omega; r_i)$ at $i$-th element of the receiving antenna has the form

$$S(\omega; r_i) = S(\omega) \cdot G(\omega; r_i, r_0),$$

where $S(\omega)$ is a spectrum of the speech, and $G(\omega; r_i, r_0)$ is the Green’s function which describes propagation channel between the talker and the $i$-th antenna element.

In a car environment the background noise is generated by the car engine, road, and wind hitting the windows. The acoustical model for the background noise field can be represented as a superposition of an infinite number of the uncorrelated random point sources located over some surface $S_0$. Using this representation, it is easy to get the spatial correlation function of the background noise

$$K_n(\omega; r_i, r_k) = \Phi_n(\omega) \int_{S_0} G(\omega, r_i, r) G^*(\omega, r_k, r) \, dr,$$

where $\Phi_n(\omega)$ is the power spectral density (PSD) of the noise sources.

In the next section we use these models to synthesize the optimal array processing algorithm.
OPTIMAL ALGORITHM

The space-time processing algorithm for estimation of the speech signal spectrum \( S(\omega) \) can be described by the linear functional

\[
\hat{S}(\omega) = \sum_{i=1}^{N} U(\omega, r_i) H^*(\omega, r_i), \tag{1}
\]

where \( U(\omega, r_i) \) is the Fourier transform of the field observed at the output of the \( i \)-th antenna element, \( H(\omega, r_i) \) is the frequency response of the filter at the \( i \)-th element of the receiving antenna, and \( N \) is the number of microphone-array elements.

In this paper we optimize the functions \( H(\omega, r_i) \) according to the optimization criteria

\[
H_{opt}(\omega, r_i) = \arg\min_{H} \left\{ \int_{0}^{\infty} E\{ | \hat{S}(\omega) - B(\omega) S(\omega) |^2 \} \ d\omega \right\}, \tag{2}
\]

where \( E\{ \cdot \} \) is the mathematical expectation, and \( B(\omega) \) is some weighting function which represents a priori desired distortion of the speech signal.

The solution of this optimization problem gives:

\[
H_{opt}(\omega, r_i) = \bar{H}_{opt}(\omega, r_i) \cdot H_W(\omega), \tag{3}
\]

where

\[
\bar{H}_{opt}(\omega, r_i) = \frac{B^*(\omega) H_0(\omega, r_i)}{\sum_{i=1}^{N} G^*(\omega; r_i, r_0) H_0(\omega, r_i)}, \tag{4}
\]

the functions \( H_0(\omega, r_i) \) satisfy the system of equations

\[
g H_0(\omega, r_i) + \sum_{k=1}^{N} K_n(\omega; r_i, r_k) H_0(\omega, r_k) = G(\omega; r_i, r_0),
\]

\[
H_W(\omega) = \frac{\Phi_\omega}{\Phi_\omega + \Phi_n(\omega)}, \tag{5}
\]

\( \Phi_n(\omega) = \{ \sum_{i=1}^{N} G(\omega; r_i, r_0) H_0^*(\omega, r_i) \}^{-1} \); \( \Phi_\omega \) is the speech signal PSD, and \( g \) is the PSD of the array internal noise.

Eq.(3) shows that optimal processing algorithm consists of two stages. The first stage (Eq.(4)) is the matched-field array processing, which is optimally reduces the background noise while maintaining the constraint

\[
\sum_{i=1}^{N} G(\omega; r_i, r_0) \bar{H}_{opt}^*(\omega, r_i) = B(\omega).
\]

It is clear that this constraint guarantees that there is no unwanted distortion in the speech signal component after matched-field array processing.

The second stage (Eq.(5)) is a single channel Weiner filter \( H_W(\omega) \). The only difference with conventional Weiner filter is that the noise component entering the filter \( H_W(\omega) \) is now the residual noise \( \bar{n}(t) \) from the first stage whose PSD \( \Phi_n(\omega) \) is lower than PSD of the original background noise.

PERFORMANCE

In this section, we compare the performance of the optimal algorithm (3) and the conventional array processing which is based on a free-field sound propagation model. We assume that the car enclosure has a rectangular shape and the Green’s function \( G(\omega; r_i, r_0) \) has the well known form [3]. The linear array used for experiments was 15 cm long and consisted of four uniformly spaced omnidirectional microphones.

Figure 1 shows respectively the waveforms of the noisy signal (signal + noise) at the first array microphone (a), output signal of the proposed array processing (b), and output signal of the conventional array processing (c).

![FIGURE 1. Waveforms of the signals.](image)

Our measurements indicate that the proposed algorithm gives substantial performance improvement of 15-20 dB in comparison with the conventional array processing, which does not take into account the effects of waveguide sound propagation in a car cabin.

References

Experimental Study on the Effect of Road Traffic Noise by using a 6-channel Recording/Reproduction System

S. Yokoyama\textsuperscript{a}, M. Ikeda\textsuperscript{b}, K. Ueno\textsuperscript{a} and H. Tachibana\textsuperscript{a}

\textsuperscript{a}Institute of Industrial Science, University of Tokyo, Komaba 4-6-1, Meguro-ku, Tokyo, 153-8505, Japan
\textsuperscript{b}Obayashi Co., kitahama-higashi 4-33, chuo-ku, Osaka-shi, Osaka, 540-8584, Japan

Psycho-acoustic experiments on the effect of road traffic noise were performed in the simulated sound field in an anechoic room using a newly developed sound field simulation technique. The experimental results of noisiness impression and disturbance in conversation are reported.

**INTRODUCTION**

In order to perform psycho-acoustical experiments in laboratories, the authors have contrived 6-channel recording/reproduction system. Using this technique, we are performing various kinds of subjective experiments on room acoustics and noise effects [1, 2]. Among them, the results of subjective experiment on the effects of road traffic noise transmitted into roadside buildings are reported in this paper. The contents of the experiment are noisiness impression and disturbance in conversation.

**EXPERIMENTAL SYSTEM**

Figure 1 shows the diagram of the 6-channel recording/reproduction system. The recording system consists of 6 directional microphones (SONY-C48), by which sounds from spatially orthogonal six directions are received and recorded onto a digital data recorder. The signals are reproduced from six loudspeakers set in the direction corresponding to the six microphones in an anechoic room. At the center point of the reproduction system, the original sound field can be reproduced accurately and natural subjective impression can be realized.

**SUBJECTIVE EXPERIMENTS**

Using the recording system mentioned above, various kinds of road traffic noises were collected in roadside buildings. Among them, twelve kinds of noises with 60 s duration time were chosen as the test sounds for the experiments.

**Noisiness**

As the first experiment, “noisiness” impression to road traffic noise was examined. The subject sat at the center point of the test sound field imaging being in a roadside building. As the test method, the magnitude estimation (ME) method and the rating scale method in five-step categories (5. extremely noisy, 4. very noisy, 3. moderately noisy, 2. little noisy, and 1. not noisy at all) were applied. 9 Japanese subjects with normal hearing ability from 22 to 26 years old participated in this experiment. The geometric average of the score obtained by the ME method and the arithmetic average of the score by the rating scale method were calculated for each test sound. Table 1 shows the correlation between the average values and the values in \( L_{Aeq} \), \( LL(Z) \), \( SIL \) and \( L_m \) [arithmetic mean value of SPL in octave bands, see ref. 3]. In these results, it has been found that “noisiness” is highly correlated to all of these noise indices. As an example, Fig. 2 shows the relationship between the score obtained by the two methods and \( L_{Aeq} \) of the test noise. In the result by the rating scale method, the judgment of category 3 (moderately noisy) corresponds to 50 dB in \( L_{Aeq} \).

(1) Disturbance in conversation
Next, the impression of disturbance in conversation was examined. In this experiment, the subject sitting at the center point of the test field and the experimenter (Japanese female, 23 years old) sitting at a point 1 m apart from the subject had a conversation in Japanese (see Fig.3). After that, the subject was asked how disturbed by the test noise during conversation in five-step categories (5. extremely disturbing, 4. very disturbing, 3. moderately disturbing, 2. little disturbing, and 1. not disturbing at all). In this study, the questionnaire was for three items; disturbance for “speaking”, “hearing” and “total conversation”. 10 Japanese subjects with normal hearing ability from 22 to 26 years old participated in this experiment. The arithmetic average of the subjective response (category number) was calculated. Table 2 shows the correlations between the average and the values in $L_{Aeq}$, $LL(Z)$, $SIL$ and $L_{m}$. From the results, it has been found that the impression of disturbance for each of the three items (“speaking”, “hearing” and “total conversation”) are highly correlated to all of the noise indices in this case, too. (It should be noted that the arithmetic mean value $L_{m}(125-4k)$ is the best among them.) As an example, Fig.4 shows the relationship between the score obtained by the experiment and $L_{Aeq}$ of the test noise. In the results, there is no significant difference between the three items. The judgment of category 3 (moderately disturbing) corresponds to 52 dB in $L_{Aeq}$.

CONCLUSIONS

From the results of the experiments on the effect of road traffic noise in roadside buildings, it has been found that both of the impressions of noisiness and disturbance on conversation can be assessed by the noise estimators like $L_{Aeq}$, $LL(Z)$, $SIL$ and $L_{m}$, and it has been suggested that “moderately noisy” and “moderately disturbing” in conversation arise at around 50 dB in $L_{Aeq}$.

REFERENCES
Sound Environments in the Intensive Care Unit (ICU) of Hospital

Nakashima H. a, Hattori T. b, Uehara K. c, Fukuyama K. d

a Osaka Institute of Technology, 1-79-1 Kitayama, Hirakata, Osaka 573-0196, Japan
b Yodogawa Christian Hospital, Osaka, Japan
c Osaka University of Arts, Osaka, Japan
d TOA corporation, Kobe, Japan

This study deals with the investigation of the sound environments in the intensive care unit of hospital and the construction of sound data-base.

INTRODUCTION

The patients and the medical staffs in the intensive care unit (ICU) of hospital are under great stress for the special situations. The sounds generated in the ICU are very important elements as well as the lighting of the room and the medical cares by nursing from the viewpoint of the mental fatigue of the patients and medical staffs.

In this study, the sounds generated in the ICU are investigated from the physical measurements and the mental aspects for the medical staffs and the patients. The results indicated that the sound environments in the ICU are in very bad situations for a lot of medical equipments and the activities of medical procedures. And then the sound data-base is built for the aim of betterment of the sound environments in the ICU of hospital.

CONSTRUCTION OF SOUND DATA-BASE

The following is the features of this sound data-base as a critical chart for each sound generated in the ICU.

1. To make out the list of sound source which are the elements of the sound environments in the ICU. We can study how to cope with each noise from this list.
2. To adopt the photos of the equipments which generate the sound. We can easily confirm the noise source from these photos.
3. To record every sound generated in the ICU.
4. To measure the physical characteristics (the frequency characteristic and sound pressure level) of each sound source. We can improve the quality and volume of each sound and sound itself.
5. To evaluate the requirement of each sound from the medical staffs and the patients.

ITEMS OF EACH SOUND ON DATA-BASE

1. The name of sound source (e.g. alarm from monitor TV, nebulizer, printer, telephon etc.)
2. Types (from a machine or human activity)
3. Requirement of sound source for the medical staffs (+ or -)
4. Requirement of sound source for the patients (+ or -)
5. Impression to each sound (very discomfort, discomfort or none)
6. Frequency characteristic of each sound with a chart
7. Sound pressure level (dB) of each sound
8. Time of sound generation (morning, daytime, evening, night or else)
9. Durations of sound generation (all day, in operation, for a moment or else)
10. Location of sound generation in the ICU, which are shown in a chart
11. Movability of sound source (+ or - or else)
12. Controllability of sound source; now (+ or -) and future (+ or -)
13. Way of improvement (hardware and software)
14. Sound retrenchment; order of priority (+ or -) and difficulty (+ or -)
15. Recorded sound
16. Photo of each sound source

RESULT OF INVESTIGATION

The results of the investigation for each item are as follows,
1. There are 66 kinds of sounds in the ICU.
2. Numbers of each type of sound are 38 for machine, 26 for human and 2 for else. In the machine sounds, the numbers of alarm sounds are 20, 8 for the operation sounds of medical equipments, 6 for other machine sounds and 4 for else sounds. In the human activity’s
sounds, numbers of the medical activities are 10, 4 for human’s movements and 12 for else.

(3) Numbers of the sound sources which are necessary for the medical staffs; they responded that 11 alarm sounds were necessary very much, and 8 alarm and equipment sounds were rather necessary in 20 signal sounds. They didn’t require the operation sounds of the medical equipments so much.

(4) Numbers of the sound sources which are movable in the ICU are 20. It is desirable to set these sound sources apart from the patients.

(5) Numbers of the sound sources which are controllable its quality and volume are 28 now.

(6) The sound pressure level for each sample sound were measured by the sound level meter, and the frequency characteristic were analyzed by the spectrum analyzer.

**CONCLUSION**

The sound environments in the ICU of hospital were investigated and its sound data-base as a clinical chart have been constructed. As the results, it is found that there are lots of questions about the sound sources in the ICU. Especially for the machine sounds, there exists 20 kinds of signal sounds and the frequency characteristics of these sounds are resemble to each other. So the medical staffs have the possibility of confusing very much. These signal sounds have monotonous sound structure, and therefore they give the uncomfortable feeling to the patients. It is necessary to improve the quality of these signal sounds. And it needs the physical improvements for the volume of signal and the noise of machine.

The aim of this sound data-base is the betterment of the sound environments in the ICU of hospital, and it is possible for the medical staffs to change the approach to sounds.

<table>
<thead>
<tr>
<th>name</th>
<th>type</th>
<th>impression</th>
<th>Requirement</th>
<th>movability</th>
<th>controllability</th>
<th>retrenchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet-nebulizer</td>
<td>machine</td>
<td>Very discomfort</td>
<td>No</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Alarm of syring pump</td>
<td>machine</td>
<td>Rather discomfort</td>
<td>Yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Emergency intercom</td>
<td>machine</td>
<td>Rather discomfort</td>
<td>Yes</td>
<td>no</td>
<td>yes</td>
<td>a little</td>
</tr>
<tr>
<td>Emergency cart</td>
<td>human</td>
<td>else</td>
<td>Yes</td>
<td>yes</td>
<td>yes</td>
<td>a little</td>
</tr>
<tr>
<td>Work table</td>
<td>human</td>
<td>Rather discomfort</td>
<td>No</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>
Possible Injuries from Vibrations to Ancient Buildings

A. Cocchi, G. Semprini

Department of Energetic, Nuclear and Environmental Control Engineering, D.I.E.N.C.A, University of Bologna, Viale Risorgimento, 2, 40136 Bologna, Italy

Modern music concerts are sometimes performed in urban areas especially in squares near cathedrals, monuments or buildings of cultural heritages that must be preserved from possible injuries. High noise levels occurring during performances may cause problems not only of hearing damage for exposed people, but also may induce vibrations on structures. This situation has been monitored during a rock concert in Modena, where both sound and vibration levels were measured. Experimental results and considerations are here presented.

INTRODUCTION

Effects of vibrations induced by a sound field incident on buildings are not well investigated because of low energy usually transferred to structures. Standards are also lacking in information on this field, taking into consideration only effects due to possible structural damages on building. Nevertheless there are many practical situations where high sound pressure levels can be a potential source of injure on specific parts of buildings (windows, plasters, fillers, etc.) especially when we are dealing with ancient buildings of cultural heritages where conservation aspects are of particular importance. Typical situation occur during modern music concerts performed in an urban area near cathedrals and ancient buildings, where high sound power levels at low frequency are emitted from loudspeakers.

This paper presents results of vibration measurements on some critical components of a cathedral during a rock concert performed in the main square of Modena (Italy).

GENERAL APPROACH

The main goal of this work was to evaluate the entity of vibration levels induced by external sound field and possible damages on building components. The only national reference standard is a guideline proposed by UNI 9916 [1] where reported vibration limits are extrapolated from DIN 4150 [2].

<table>
<thead>
<tr>
<th>Type of structure</th>
<th>Vibration velocity [mm/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>foundation</td>
</tr>
<tr>
<td>&lt;10 Hz</td>
<td>10-50 Hz</td>
</tr>
<tr>
<td>Industrial Buildings</td>
<td>20</td>
</tr>
<tr>
<td>Residential buildings</td>
<td>5</td>
</tr>
<tr>
<td>Structures of great intrinsic value</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1. Vibration velocity limits proposed by DIN 4150

Vibration levels, measured on a glass window, on a stucco decorated balcony and on a little column, are simultaneously recorded with façade sound pressure levels in order to correlate both phenomena.

In the third octave band analysis the significant frequency range is from 20 Hz to 600 Hz: the lower one depending on the effective kind of music performed and of response of reproducing devices, the higher depending on maximum resonance frequency of structures analysed.
Because of the sensibility of vibration transducers to high sound fields, the response of an accelerometer with and without structural connection has been compared, showing the irrelevance of the maximum sound field on vibration measurements.

RESULTS

Acoustic Measurements

Sound pressure level time history depend on musical piece performed: for a typical piece, the cumulative distribution is shown in figure 2 where most of the sound pressure is bigger than 110 dB.

In the frequency domain, typical spectrum is shown in figure 4, where maximum levels occur at low frequencies (40-50 Hz) and at middle frequencies (400-800 Hz).

Vibration Measurements

Analysis of vibration levels on different components shows a strong correlation to the external acoustic field and reveals main resonance frequencies of structures.

Highest vibration velocity occurs on window than other components; maximum values of about a 0.7 mm/s have been measured at low frequencies (50-63 Hz), lower than limits proposed by DIN standard. Resonance of balcony at 125 Hz is also relevant.

CONCLUSIONS

Vibrations on buildings induced by high sound levels can be a potential damage factor, depending on kind and condition of the component and of sound pressure levels incident on it. For the situation here investigated vibration levels are less of any standardised limit related on building damage.

Nevertheless because vibrations levels are very high compared to background conditions, problems can occur when some building components are in critical static situation.

ACKNOWLEDGEMENTS

This work has been developed under the agreement with the municipality of Modena, and of support of "Studio PGM" of Medolla (MO) and "Studio A" of Modena.

REFERENCES

1. UNI 9916 - Criteri di misura e valutazione degli effetti delle vibrazioni sugli edifici - 1991
2. DIN 4150 (part 3) Structural vibration in buildings - 1986
Higher Rate of Low-birth-weight and/or Preterm Infants Observed around Kadena Airfield in Okinawa

T. Matsui\textsuperscript{a}, T. Matsuno\textsuperscript{b}, K. Ashimine\textsuperscript{c}, K. Hiramatsu\textsuperscript{d}, Y. Osada\textsuperscript{e} and T. Yamamoto\textsuperscript{f}

\textsuperscript{a}Department of Hygiene, Asahikawa Medical College, Asahikawa 078-8510, Japan, matsui@asahikawa-med.ac.jp
\textsuperscript{b}Okinawa Nanbu Health Center, 901-1104, Japan. \textsuperscript{c}Okinawa Chubu Hospital, 904-2293, Japan
\textsuperscript{d}Mukogawa Women's University, 663-8558, Japan. \textsuperscript{e}Institute of Public Health, 108-0071, Japan
\textsuperscript{f}Kyoto University, 606-8501, Japan

The birth weight and the length of pregnancy were analysed using 164,028 birth records from 1974 to 1993 in the 14 municipalities around the Kadena airfield, Okinawa. The municipalities were classified according to the population weighted average $L_{dn}$. Multiple logistic regression model was applied to obtain the odds ratios on low-birth-weight and/or preterm infants with adjustments for some confounding factors. The odds ratio in Kadena Town, which is the most highly noise exposed municipality, was 1.3 for the low-birth-weight infants. The trend test showed significant dose-response relationship between the odds ratio and $L_{dn}$.

INTRODUCTION

It is generally recognized that the mental stressor possibly causes various kinds of physical impact upon human beings through the endocrine and nervous systems. Noise can be a stressor to cause such stress reactions as many mental stressors might do to human bodies.

Many papers have been published to report the results of animal experiments and epidemiological researches suggesting the effect of noise on pregnancy; that is the noise exposure is a factor reducing birth weight and/or shortening the length of pregnancy.

This paper examines the birth weight and the length of pregnancy with relation to the noise exposure around the U.S. military airfields (the Kadena and the Futenma airfields) in Okinawa.

MATERIALS

Japanese government accumulates the birth records including the information on date of birth, birthplace, birth weight, sex, single or multiple pregnancy, the length of pregnancy, live birth order, legitimacy of the infant, mother’s age, experience of stillbirth, occupation of householder, etc. The number of births in Okinawa Prefecture recorded for 20 years from 1974 to 1993 was 356,549 among which 164,028 records in 15 municipalities around the Kadena and the Futenma airfields were analysed statistically.

The residential areas around the two airfields are classified by noise measure of WECPNL, which was defined by the Defense Facilities Administration Agency (DFAA) in 1978. In this study, WECPNL was translated into $L_{dn}$ based on the noise measurements carried out by the DFAA.

METHODS

The birthplace is recorded in the name of the municipality and no further information is available to identify the noise exposure during pregnancy. In order to analyse the association with the noise exposure, population weighted average $L_{dn}$ was calculated for each municipalities based on the community population available as of June 1, 1995.

The birth weight under 2,500g was categorized as low-birth-weight. The data of multiple pregnancy and the records of the mothers having experience of stillbirth were excluded from the analyses, because they have higher risk of low-birth-weight. WHO has defined preterm birth as birth before the 37th week of pregnancy. However, another classification, birth before the 10th month, had been used in Japan until 1978. The records before 1979 were excluded from the analysis of preterm infants.

Multiple logistic regression analyses were applied to the birth rate of low-birth-weight and/or preterm infants adjusting for sex, mother’s age, live birth order, occupation of householder, legitimacy of the infant, year of birth and the interaction of mother’s age and live birth order. Trend analyses were also carried out to examine the dose-response relationship between the average $L_{dn}$ and birth rate of low-birth-weight and/or preterm infants.

RESULTS AND DISCUSSION

The 15 municipalities were classified into 4 groups according to the average $L_{dn}$ as in Table 1. The eight municipalities with $L_{dn}$ under 60 dB were treated as the control.

In Table 2 are presented the numbers of births and the birth rates of low-birth-weight infants in 4 groups. The
Table 1. Population weighted average $L_{dn}$

<table>
<thead>
<tr>
<th>$L_{dn}$ (dB)</th>
<th>Municipalities around Airfields</th>
</tr>
</thead>
<tbody>
<tr>
<td>70–75</td>
<td>Kadena Town (73.0 dB)</td>
</tr>
<tr>
<td>65–70</td>
<td>Chatan Town (68.5 dB)</td>
</tr>
<tr>
<td>60–65</td>
<td>Okinawa City, Gushikawa City, Ishikawa City, Ginowan City and Yomitan Vil.</td>
</tr>
<tr>
<td>&lt;60</td>
<td>Urasoe City, Katsuren Town, Nishihara Town, Onna Vil., Kin Vil., Yonagusuku Vil., Kitanakagusuku Vil. and Nakagusuku Vil.</td>
</tr>
</tbody>
</table>

Table 2. Rate of low-birth-weight infants

<table>
<thead>
<tr>
<th>Municipalities</th>
<th>Num. of Births</th>
<th>&lt;2,500g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kadena Town</td>
<td>4,425</td>
<td>366 (8.3%)</td>
</tr>
<tr>
<td>Chatan Town</td>
<td>6,066</td>
<td>423 (7.0%)</td>
</tr>
<tr>
<td>Okinawa City, etc.</td>
<td>92,332</td>
<td>6,439 (7.0%)</td>
</tr>
<tr>
<td>Control</td>
<td>57,637</td>
<td>3,667 (6.4%)</td>
</tr>
</tbody>
</table>

The results of multiple logistic regression analysis are shown in FIGURE 1. The adjusted odds ratio on low-birth-weight is plotted as a function of average $L_{dn}$ with 95% confidence interval. The asterisks in the figure show significant probability of odds ratio referred to the control (\(*: p < 0.05, \**: p < 0.01, \***: p < 0.001\)). The result of the trend test suggests that significant dose-response relationship ($p < 0.0001$) exists between the birth rate of low-birth-weight infants and the noise exposure.

In Table 3 are shown the rates of preterm births. The preterm birth rate in Kadena Town is 1.5% higher than the control. The odds ratio on preterm birth is shown in FIGURE 2 as a function of $L_{dn}$. As was found in the case of low-birth-weight, highly significant dose-response relationship is detected ($p = 0.0008$).

It has been reported that smoking habit raises the birth rate of low-birth-weight infants by 50 to 100% [1, 2, 3]. Since the obtained odds ratio is not adjusted for smoking habit, it might be confounded by the rate of smoking.

Assuming that the higher rate of low-birth-weight infants in Kadena Town is attributed entirely to the smoking habit with odds ratio of 2.0, the rate of maternal smoking in the town must be 40% higher than the control. In our survey, however, no significant difference in female smoking rate was found among municipalities around the Kadena airfield.

We can extract conclusions that the aircraft noise exposure might cause the higher birth rate of low-birth-weight and/or preterm infants observed in Kadena Town where the residential area adjoins the Kadena airfield.

REFERENCES

Field Attenuation of Hearing Protection Devices

A. Peretti\textsuperscript{a,b}, F. Pedrielli\textsuperscript{c}, G. Strumia\textsuperscript{d} and M. Baiamonte\textsuperscript{b}

\textsuperscript{a}Scuola di Specializzazione in Medicina del Lavoro, Università di Padova, Italy
\textsuperscript{b}Peretti e Associati sas, Padova, Italy
\textsuperscript{c}CEMOTER Institute, National Research Council of Italy, Ferrara, Italy
\textsuperscript{d}Fenice SpA, Centro Servizi Ecologici, Orbassano (TO), Italy

Although personal hearing protection devices should not be the permanent answer to noise exposure reduction, their use represents a temporary solution until adequate engineering controls or administrative strategies reduce the noise hazard. This paper describes the researches aimed at developing standardised test methods that reduce the discrepancy between the labelled attenuation of hearing protection devices and the much lower attenuation actually attained by workers using these devices on the job. First, it reports a short review of the technical procedure standardised world-wide and currently used to assess the attenuation of hearing protectors. Second, it reviews the results of real-world studies conducted in order to determine the field performance of these personal devices. Then, it outlines a new standardised testing procedure that should yield a more realistic estimate of the field performance of hearing protection devices.

THE LABELLED ATTENUATION

The standardised test protocol for obtaining real-ear attenuation data used for product labelling purposes is defined in ISO 4869-1 \cite{1}. The test shall be performed in a room under diffuse sound field conditions. The test signals may be reproduced by means of a loudspeaker system and shall consist of a pink noise filtered through one third octave bands centred at 125, 250, 500, 1000, 2000, 4000 and 8000 Hz. The test consists in the determination of the hearing threshold both with open ears and with the hearing protector in place, for each of the sixteen subjects selected for the test. The difference, in decibels, of the two hearing thresholds represents the sound attenuation exerted by the device under test.

This test is aimed at yielding an optimal protector performance. In fact, the test procedure involves many steps under the supervision of the experimenter: instructions on how properly to fit the hearing protector, selection of the proper protector size, verbal clarification of the manufacturer’s written instructions, assistance in adjusting the device in conformance with those instructions, removal and re-insertion of the device as to obtain the best attenuation while listening to a broad-band random noise (in this step, the subject has to make several movements of the head and of the jaw), and a final check of the proper fitting of the device by the experimenter. Then, when the definitive test begins, any further manipulation of the hearing protector is prohibited.

The sound attenuation is not the same for each subject, but depends on the proper fitting of the device, on the measurement uncertainties, as well as on the different size and shape of the ear canal, of the pinna, and of the head. To account for this variability, the spectral sound attenuation is reported in terms of statistical values. These data appear on the manufacturers’ on-package instructions and shall include the mean value and the standard deviation, at least.

THE FIELD PERFORMANCE

In the previous paragraph, it has been shown that the test procedure defined in ISO 4869-1 is based on the optimal fit of the hearing protection devices. Therefore, the labelled attenuation is the best performance the protectors may achieve. Unfortunately, these attenuation values can never be matched by workers wearing these devices on the job. This means that the laboratory attenuation data provided by the manufacturers are almost always unreal. Since the assessment of the noise exposure refers right to these attenuation data, the hearing conservation programs based on the use of these protectors become actually unreliable.

In the last two decades, studies have been published indicating that data derived from laboratory tests should never be used for the assessment of the field performance of the hearing protectors. A review of many of these studies \cite{2,3}, in fact, showed that the mean attenuation actually attained by workers is always lower than the mean values provided by the manufacturers. Moreover, the standard deviation of the field attenuation data is always greater than that provided by the manufacturer.

A field investigation conducted in many industrial plants concerning different types of earplugs \cite{4}, showed that the attenuation from the laboratory data
versus that from the field data is strongly reduced (29 dB versus 7 dB) for the pre-formed earplugs. This difference is prominent also for both acoustic wool earplugs (26 dB versus 10 dB) and acoustic foam types (36 dB versus 20 dB). Only for custom-moulded types, the difference between the two attenuation values is less noticeable (20 dB versus 14 dB). Hence, serious underprotection could result if one assumes that the workers will be receiving the laboratory-established attenuation levels. As an example, if a 20 dB overassessment occurs in the attenuation values, an estimated noise exposure of 70 dB(A) could result in effective noise exposure of about 90 dB(A). Therefore, many of the workers think they are protected but they are not.

**A NEW TESTING PROCEDURE**

Since the end of 1980’s, it has been emphasised the importance of developing a testing procedure that should give a more realistic estimate of the field performance of hearing protection devices. Therefore, Working Group S12/WG11 of the Acoustical Society of America assisted [2,5] the Accredited Standards Committee on Noise in the preparation of a new standard (ANSI S12.6-1997) that yields to noise attenuation values that workers may actually receive from wearing their hearing protectors in occupational settings [6].

This procedure is similar to the ISO one and is based on psychophysical tests conducted on human subjects to determine real-ear attenuation at threshold. In the protocol, two methods are provided, differing in their subject selection, training, hearing protector fitting procedures, and experimenter involvement, but corresponding in all the other technical aspects. The first method, designated *experimenter-supervised fit*, is intended to describe the upper limits of hearing protector performance and is nothing but the procedure depicted in the ISO standard with an outstanding influence of the experimenter on the tested subjects. The second method, designated *subject fit*, is intended to have greater correspondence to most real-world situation. The innovative aspects of this method are that it is conducted with persons naive with respect to the use of hearing protection devices and that the experimenter involvement is kept to an absolute minimum. In fact, the subject shall be handed the hearing protector in the packaging in which it is sold, along with the manufacturer's written fitting instructions that would normally accompany the device. Then, the subject shall fit and adjust the hearing protector in both ears without any fitting noise, and any verbal or physical assistance from the experimenter.

**CONCLUSIONS**

The conditions under which hearing protection devices are tested and rated for attenuation are quite different from those in the environments where these devices are actually used. Moreover, in practice, a wide range of attenuation values may be observed in the workplace: from essentially no attenuation at all for devices poorly fitted by untrained users who incorrectly and inconsistently wear their protectors, to much higher levels of protection that may be obtained under optimal conditions in workplaces where successful training programs are applied.

The discrepancy between laboratory and real world attenuation data is mainly due to the following aspects:
- no training or inadequate instruction on how to don the hearing protection devices (especially for acoustic foam earplugs);
- wrong selection of the protector size (especially for pre-formed earplugs);
- displacement of the device due to temporomandibular or heavy work related movements (especially for pre-formed and acoustic wool earplugs);
- alteration or damage of the devices.

An approach to reduce this discrepancy would be to adopt new standard procedures of measuring hearing protector attenuation which do not tend to achieve an optimal performance. At the same time, however, the attenuation achieved at the workplace should be optimised. Such improvements can be better achieved with the help of program management, education and motivation of the work force, enforcement of proper devices utilisation, and with the development of easier-to-use and more comfortable hearing protectors.

**REFERENCES**