Requirements for the protection against aircraft noise

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Germany 2003/2004

in press

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Summary

In preparation of the revised edition of the Air Traffic Noise Act the Federal Environmental Agency formulated targets for aircraft noise control. They were prepared oriented to the Federal Immission Control Act. The assessment periods were chosen analogously to the regulations on other traffic noise sources (rail traffic, road traffic). The control targets cover the following affected areas

- aural, extra-aural health
- night's sleep
- annoyance
- communication
- recreation.

Considerable nuisance can be avoided by limiting the exposure to aircraft noise (outside) to equivalent levels below 55 dB(A) by day and 45 dB(A) at night, and impairment of health can be avoided by limiting the exposure to aircraft noise (outside) to equivalent levels below 60 dB(A) by day and 50 dB(A) at night.

Introduction

Our living conditions may be affected by sounds in many ways. Any sound which may cause disturbances, annoyance, impairment or damage is referred to as noise /1/. Noise may not be determined by means of physical measuring methods as noise is the result of a cognitive examination of sounds. It is possible to measure the physical properties of sound, sound pressure, sound spectrum etc. Sound events, e.g. an overflight or a multitude of diverse sound events, are measured over a defined time period. An equivalent sound pressure level (L_{eq}) is used for the characterization over a longer period /2/. Such an equivalent level predicts about one third of the span of the individual annoyance reaction to noise. Today it is the maximum which measured physical values may provide as regards noise perception. That means, two thirds of the reactions to noise are not connected with sound pressure and what is physically measurable of it. They are, i. a., the expression of actual personal dispositions and intentions, dependent on gender, social status and many other things. As has been already mentioned, noise may affect the living conditions in many ways, e. g. primarily communication, recreation and relaxation in the dwelling, yet also in the exterior residential area, concentrated mental work, the psychical state of health and the use of the dwelling are affected. The sum of all disturbances, feelings owing to noise exposure in a specific situation is referred to as annoyance. Annoyance belongs to the main effects of environmental noise. Annoyance is the decisive value for assessing noise exposure. Permanent strong environmental noise may cause impairment of health apart from annoyance.

Impairment and annoyance

Existing situations of exposure

Annoyance is assessed by individual experience made with the exposure situation. Representative public surveys are especially suited for assessing noise situations as they consider also non-acoustic influencing factors. According to the representative survey relating to environmental consciousness conducted by order of the Federal

Minister for the Environment, Nature Conservation and Nuclear Safety in 2002 /3/ road traffic is now as before the dominating noise source in annoyance perception. In addition to road traffic and neighbours air traffic is one of the most important sources of noise annoyance in Germany. Table 1 contains the annoyance data collected in 2002. Compared with the survey conducted in 2000 /4/ only insignificant changes are to be detected for most of the sources. As to aircraft noise, however, the share of the people, who are not at all disturbed or annoyed is declined in Germany. Extrapolated about 4 million more people feel annoyed by aircraft noise in 2002 than in 2000, altogether now roughly 30 million of citizens of the Federal Republic of Germany are annoyed by aircraft noise.

Noise annoyance in Germany in 2002

Level of annoyance	extremely disturbed and annoyed	highly disturbed and annoyed	moderately disturbed and annoyed	slightly disturbed and annoyed	not at all disturbed and annoyed
Noise Source	Data in %				
Road traffic	5	12	20	28	35
Neighbours	2	4	11	23	60
Aviation	2	5	9	21	63
Industry and commercial	1	3	8	15	73
Railway traffic	1	4	7	11	77

Table 1: Noise annoyance by various sources in Germany, Results of survey conducted in 2002

These representative surveys of the population relating to noise annoyance are of a high importance to environmental policy activities. To support the limit values set data relating to the noise exposure of the interviewees are required in addition: dose-effect relations are a suitable basis for making political decisions. The dose-effect relations allow to predict the reactions of the population to annoyance. Various studies show a clear connection between exposure and annoyance in the above-mentioned order of magnitude /5/. Usually acoustic measures based on equivalent permanent sound levels (L_{eq}) are used to characterize noise exposure. In most of the studies „highly annoyed“ is used as valuation criterion (% HA). Persons, who respond to the upper 27 % - 29 % of the given, partly very different reply scales /6, 7, 8/ are assessed as highly annoyed. We proceed on the fact that if “highly annoyed” is indicated non-acoustic moderators have a smaller influence on the assessment and the correlation between exposure to sound and annoyance assessment is high /6/. In the European Union directive relating to environmental noise /9/, however, a deviating criterion is envisaged. Figure 1 contains examples of the dose-effect relations.

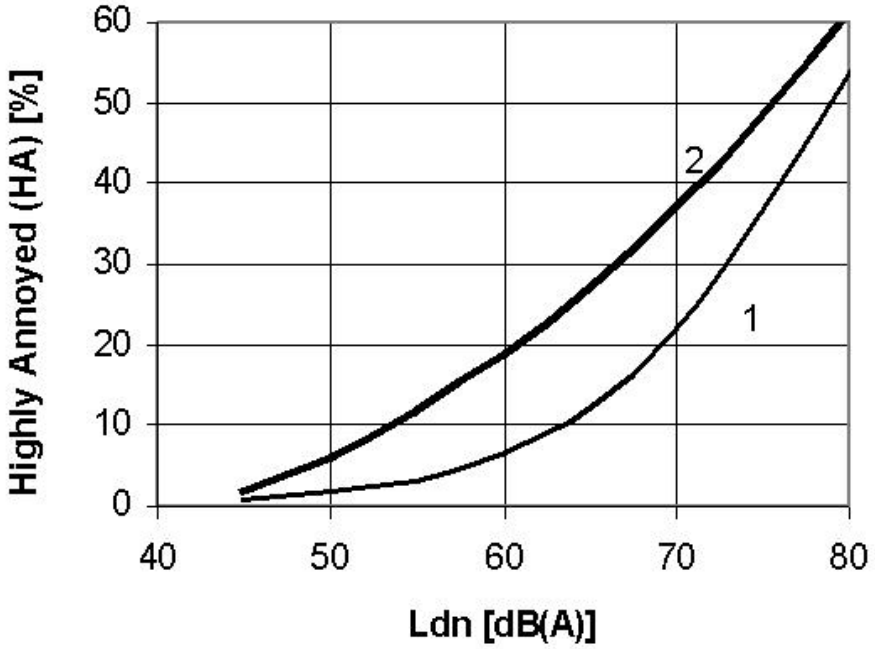

Figure 1: Relation of exposure and annoyance, highly annoyed (% HA)
1: FICON 1992 /10/
2: Gezondheidsraad 1997 /11/
Ldn = 24h equivalent level (15 hours by day and 9 hours with an additional supplement of 10 dB at night)

Whereas the results of numerous studies of the perception of annoyance by all types of traffic are summed up in curve 1 published by the Federal Interagency Committee On Noise /10/ curve 2 is based on studies of aircraft noise only.
After analyzing the available papers on the connection between noise exposure and annoyance on the basis of groups of persons and existing situations may be summed up as

- a bigger number of interviewees feels annoyed or highly annoyed by aircraft noise as compared with road traffic noise in the event of the noise exposure being equal (aircraft noise malus). The malus is differently indicated in the individual studies. It depends a. o. on the exposed area under consideration. Frequently a malus of approx. 5 dB is mentioned /12, 13/.

<u>Problems of a definition „considerable nuisance”</u>
In Germany immission control is largely regulated by the Act on the Prevention of Harmful Effects on the Environment caused by Air Pollution, Noise, Vibration and Similar Phenomena (Federal Immission Control Act). The purpose of this Act is, inter alia, to protect human beings from hazards, considerable disadvantages and considerable nuisance. However, it is not specified what a considerable nuisance is. Some experts explain that an exposure where at least 25 % of the people affected classify themselves as “highly annoyed (HA)” is to be considered as limit to considerable nuisance. They refer to papers by Grandjean and others 1969 /14/,

Tracor 1972 /15/ and Rohrmann 1978 /16/. Yet, this conclusion cannot be drawn from these papers. In the article by Grandjean and others you find comparable numbers, yet the data does not refer to high annoyance or the reply category „highly annoyed“. The authors suggest to designate 20 - 25 % complaining when questioned spontaneously, and 30 – 40 % complaining in the case of being directly questioned as a considerable part of the population. Comments on the degree of annoyance are not connected with these suggestions. In addition, it might be definitely critical whether 20 % or 40 % of the population are to be regarded as a considerable or an insignificant proportion.
According to /15/ the aircraft problem is only of a “serious nature” if more than 25 % are “highly annoyed” or the number of official complaints reaches 30 % (quoted according to /16/, p. 227). The values indicated here are pure settings and do not define the limit for a considerable annoyance.
Rohrmann himself has not mentioned numbers but showed the difficulties in fixing appropriateness limits, their modifiability and the inadequacy of acoustically defined limit values (/16/, S. 234, /17/, p. 140) in a diagram. The above-mentioned values may not be derived from them.
The question which exposure allows to assess annoyance in the sense of the Federal Immission Control Act as considerable may not be exclusively answered by noise effect research. On the one hand, annoyance and impairment do not show remarkable changes with the exposure growing (strength, duration, frequency) but increase continuously. On the other hand, such appropriateness limits are rather social and political settings which moreover require weighting up these against other social values than empirical facts discoverable by means of scientific methods. This may be, i. a., recognized by the fact that decrees, administrative regulations and ordinances which so far fixed immission limit or standard values for the prevention of harmful effects on the environment by sounds, which are not based on uniform effect standards. As methods of assessment differ in source-specific regulations (partly source-specific differences of annoyance are considered by additions or reductions (16^{th} Ordinance on the implementation of the Federal Immission Control Act); the differences in annoyance are partly expressed in different indicative values (German standard DIN 18005 “Sound proofing in city construction”, Part 1 – orientation values at night)) we may not proceed on the fact that with the level of assessment being equal an equal effect of annoyance is to be expected. Considerable source-specific differences may rather exist which depend, in addition, on the level of exposure. That is why methods of assessment and the respective indicative values for immissions may not be applied schematically to other noise sources. However, the indicative values for immissions fixed for the various noise sources allow to draw comparisons relating to the level of sound proofing /18/.
From the analysis of the available studies we may draw the conclusion that

- annoyance reactions start by day at 50 dB(A) (Leq; 16h; outside);
- the beginning of considerable annoyance by day has to be seen at equivalent levels (Leq; 16h; outside) of 55 dB(A).

Change of the annoyance situation
Investigations of changes of the annoyance reactions - as it is required for assessing essential changes or a new construction, e.g. construction of a new runway or a new airport - are available only to an insignificant extent. Indications that in the event of the exposure being increased disproportionately more persons feel annoyed or highly annoyed are to be found in the publications on the airport Vancouver /19/. The investigations were carried out 1½ years before and little less than 2 years after a

new runway was opened. In 3 areas of investigation the exposure changed by 1, 3 and 7 dB(A) after the opening. Figure 2 shows the changes of the annoyance reactions resulting from it.

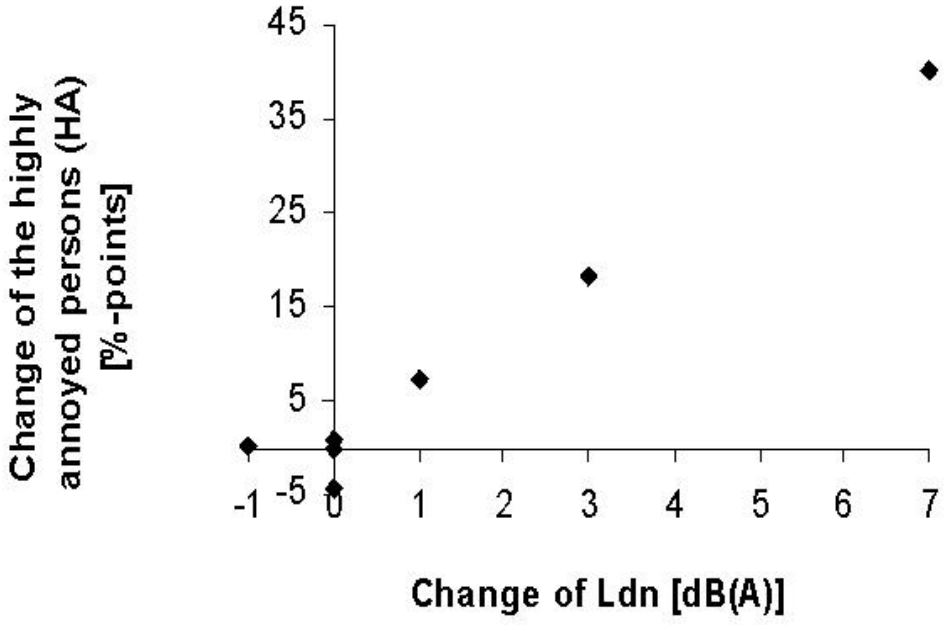

Figure 2: Airport Vancouver, change of the annoyance reactions depending on the change of the exposure situation by opening of a new runway.

Figure 3 shows the relation of exposure and annoyance before and after the change. The regression straight lines are plotted.

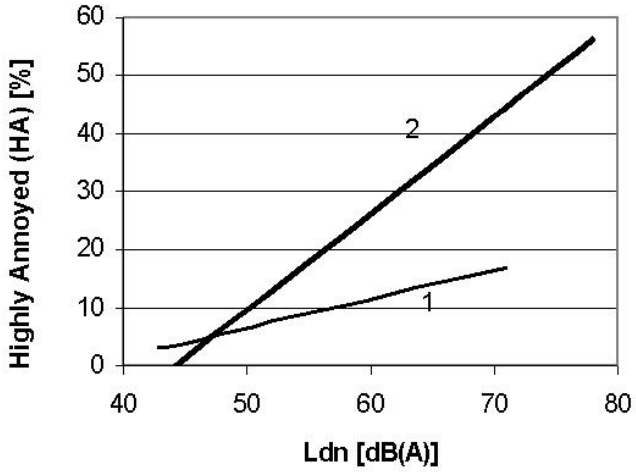

Figure 3: Airport Vancouver: Relation of exposure and annoyance, highly annoyed (% HA) 1: before opening a new runway; 2: after opening a new runway

The results obtained at the airport Vancouver point to the fact that

- in the event of the exposure situations being changed the dose-effect relations /8, 10/ known underestimate the annoyance reactions and the beginning of high annoyance is, in these cases, below a L_{eq} of 55 dB(A) by day;
- as compared with the “actual situation” in the event of a change the same annoyance reaction (% HA) is to be detected with the exposure being considerably lower (In the exposed area of the actual situation of about L_{dn} = 60 dB(A) the difference is e.g. approx. 7 dB(A)).

In Switzerland there was observed that the temporal development of aircraft noise exposure had clear effects on the housing quality. In the canton Zurich there is a distinct housing shortage; in 2002 the housing vacancy was clearly below half a per cent. However, the communes Opfikon and Ruemlang situated in the entrance area of the Zurich airport Kloten showed a housing vacancy by about 13 times higher in Opfikon and by further 5 times higher in Ruemlang than in the agglomeration area Zurich. Both communes were nearly identically exposed to aircraft noise in 2002. In the annual average the L_{dn} was 68 dB(A) and 67 dB(A) respectively in Ruemlang. The housing vacancy by 2.5 times higher in Opfikon as compared with Ruemlang may be explained by a clearly different development of noise exposure in the two communes. Whereas the aircraft noise exposure by day has declined by 7 dB(A) from 75.5 dB(A) to 68,5 dB(A) in Ruemlang since 1986 it was not possible to state such a comparative improvement of the housing quality in Opfikon in this period, as Figure 4 shows. Interpreting the housing vacancy as an indicator for housing quality this example shows that a temporal development of exposure which means an improvement of the noise situation in the long term is extremely significant for assessing the housing quality.

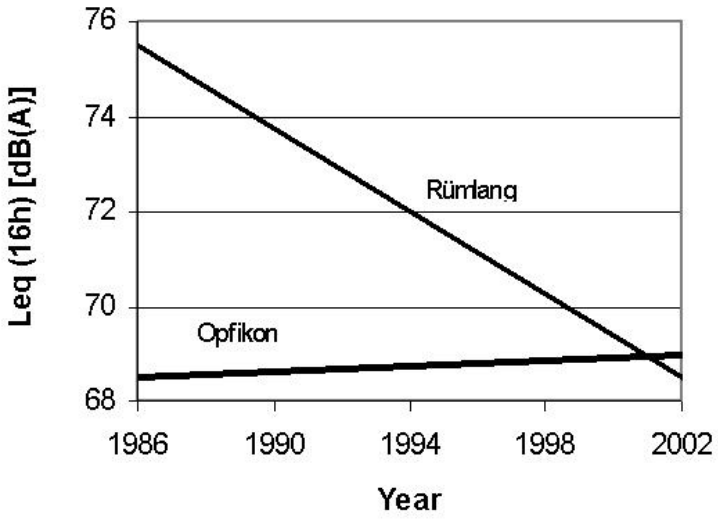

Figure 4: Development of aircraft noise exposure in Opfikon and Ruemlang

Disturbance of communication

Communication plays a major part for the development of the personality and for social development. Disturbance of communication (entertainment, telephoning, tv, listening to the radio) are accompanied by hazards (danger signals are not perceived), annoyance and change of the behaviour such as louder speaking, interruption of speaking or increase of attention in listening, thus resulting in a reduction of well-being. Disturbance of communication is frequently mentioned in surveys /20/. It arises if the desired sound (e.g. speech) is completely or partly masked by undesired sound (noise). In quiet surroundings persons prefer a speech level measured at a 1 m distance of 54-60 dB(A) /21/. The interdisciplinary working group for noise effects in the Federal Environmental Agency /22/ gives a slightly lower average speech level measured at a 1 m distance of 50 – 55 dB(A) in the case of a quiet way of speaking.

To achieve a good to excellent intelligibility the level of noise has to be at least by 10 dB(A) lower than speech level. At a distance of the hearer of 1 m this would, mean on average a noise level of maximally 45 dB(A). Yet, this distance of 1 m is seldom met in the house and in the social area rather not at all but mostly the distance of speech is bigger. As at farther distances the hearer perceives a lower “speech level”, e.g. in the case of the distance being doubled to 2 m it will be by 6 dB(A) lower at a free sound propagation, only a noise level reduced to the same extent will be admissible (approx. 40 dB(A) to achieve the same quality of intelligibility.

As is known, intelligibility depends also on the spectral properties of disturbing noise apart from the signal-noise ratio. Penetrating sounds filtered by exterior building elements show a modified spectrum in contrast to the original (exterior) noise which is to be considered for assessing the communication situation. The Federal Environmental Agency /23/ carried out respective investigations considering 7 typical window constructions of the noise control classes 2 – 5 in Germany and average overflight spectra of jet propelled aeroplanes when taking off and landing. An undisturbed communication was defined according to the articulation index by Kryter at a height of Al = 0.5. This Al corresponds to a monosyllable audibility of 75 %. The criterion was observed if the overflight level did not exceed the indoor values of about 43 dB(A), on average, when landing and about 45 dB(A) when taking off.

According to the available results of investigations, intelligibility may be assessed in a simplified way by means of the way of speaking, the distance between speaker and listener and noise level as follows:

- Adults with a normal hearing capacity show a good intelligibility in rooms of a usual size and equipment if the noise level is below 40 dB(A) in the case of a quiet way of speaking.
- Outside the buildings, in principle, the same criteria apply as indoor. However, it is assumed that as regards communication in the open the expectations are not so high, the speaker is expected to make efforts. As to disturbance of communication by day equivalent levels above approx. 50 dB(A) are to be expected. A speech level above 60 dB(A) is considered to be strenuous and annoying.
- Higher demands for conditions for a good to excellent intelligibility are to be made in the case of younger children as they owing to their acoustic memory being not yet fully developed are not in a position to distinguish similarly sounding words at disturbance levels not resulting in a reduction of the intelligibility for adults.

Impairment of night's sleep

Sleep serves the physical and psychical recreation. Recreation depends on the duration and continuity of sleep. "Not restful sleep" is connected with restrictions of health, the mental and physical efficiency, participation in the professional and social life and resulting from it restrictions of the quality of the life of the people affected. "Not restful sleep" is becoming a socially relevant and sociomedically important problem in addition its disturbance of health /24/.

Physically measurable deviations from the normal sleeping process also detected by means of sociopsychological methods designate sleep disturbances (/25/, p. 123 ff.). Sleep may be disturbed by various influences. Acoustic stimuli belong to exterior influences affecting sleep.

In many studies relating to the effects of noise on sleep also data on the psychological effects of noise at night are collected by surveys apart from the data measured physically. As in surveys relating to annoyance by day they are compared with the objective noise exposure detected mostly for a group of interviewees in a representative measuring point outside residential buildings. Equally as the replies relating to annoyance by day the data relating to the disturbance of night's sleep depend on a multitude of factors (age, physical health etc.). Difficulties in falling asleep, repeatedly falling asleep and waking up and tiredness the following day are mentioned as a deterioration in the quality of sleep experienced. Apart from that, also shutting of the windows required for sleeping through or falling repeatedly asleep is mentioned as annoying.

Figure 5 shows in an exemplary way the relations between annoyance at night and the highly sleep-disturbance annoyed persons (HS %).

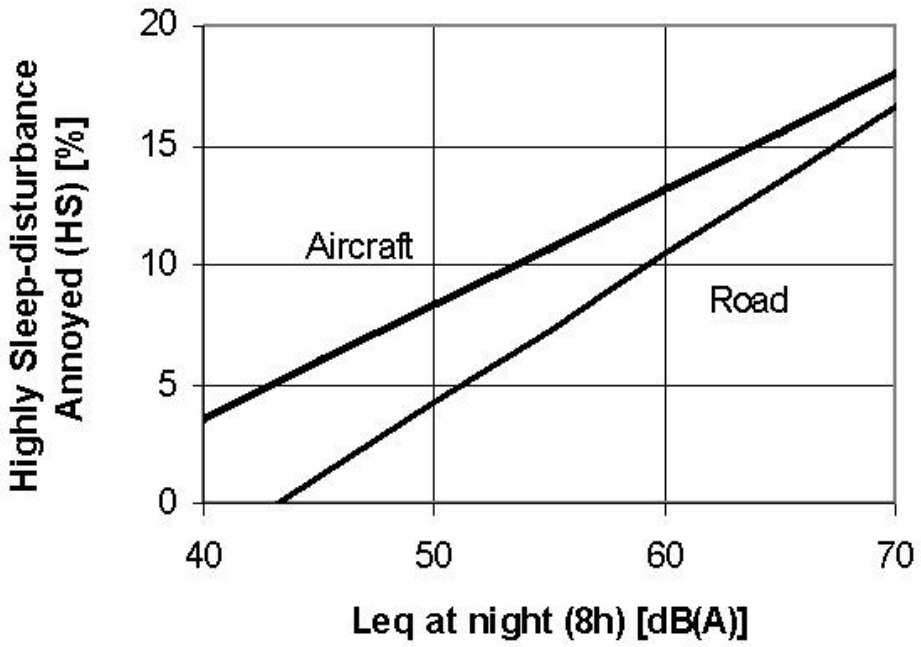

Figure 5: Relation of exposure and number of highly sleep-disturbance annoyed persons (HS) Gezondheidsraad 1997 /11/

After analyzing the papers available on the relation between exposure and annoyance at night we may summarize that

- sleep disturbance is reported from about L_{eq} of 40 dB(A) upwards outside at night;
- high annoyance related to aircraft noise is observed above L_{eq} of 45 dB(A) outside at night;
- as to its annoyance effect aircraft noise exceeds road traffic. Thus, it should be given a malus for the assessment period night or the weighting implied in L_{den} should be newly adjusted.

In the past and partly still today we have been speaking of a sleep disturbance if we remembered that noise caused waking up. According to findings obtained in sleep research in the last 20 years, sleep disturbance not leading to waking up (no visible arousal reactions in the EEG or changes in the behaviour), may have partly so strong effects on sleep that the next day efficiency will not be unrestrictedly given. Available results show that follow-up damage caused by sleep disturbance may not be excluded /26/. If and which changes will be relevant to health and to which extent has not yet been finally clarified. That is why impairment of sleep has to be considered extremely critically. The results of laboratory investigations and epidemiological studies vary partly considerably. There are clear differences as regards the reliability of the data. Figure 6 shows a curve summarizing the results of a few aircraft noise studies.

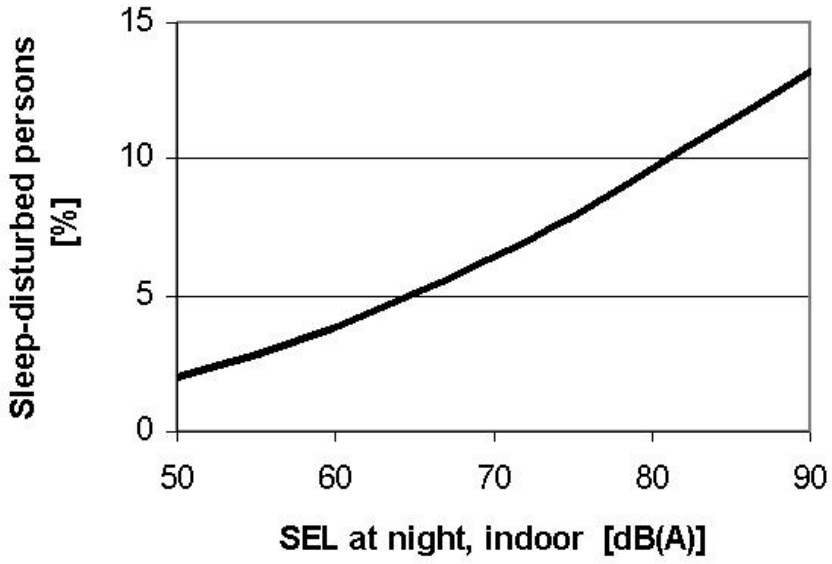

Figure 6: Relation of exposure and persons with waking-up reactions/changes of sleep stages (results of a few field studies), FICAN 1998 /27/ SEL = Sound exposure level

The results of the physiological investigations of the effects of noise on night's sleep show that

- single noise events above 50 dB(A) (L_{max}, indoor) result in changes of the sleeping process or waking up;
- at permanent sound levels (L_{eq} < 30 dB(A), indoor) a largely undisturbed night's sleep might be still possible.

Risks of cardiovascular diseases

Since a longer time the hypothesis exists, that a high noise exposure over many years provides an increased risk of cardiovascular diseases is the object of research activities.

This hypothesis is derived from the general stress model. Noise causes non-specific stress reactions. People awake react directly to exposure to noise or in the case of noise annoyance indirectly by an increased secretion of various stress hormones, changes of blood pressure and heart rate and contractions of the outer blood vessels. A short-term occurrence of these reactions - as we can experience them also in specific situations without noise effects (e.g. examinations) - is probably without relevance to health. The above-mentioned reactions occur as a reflex at instantaneous levels above approx. 60 dB(A), yet may be also observed in the case of biologically relevant signals (cracks, speech) and, depending on the emotional situation (annoyance, fear) may be already observed at very low levels. During the reactions sensitization and habituation play an important part. A long lasting noise exposure (over a few years) may cause a permanent shifting of the physiological equilibrium. This may result in chronic damages of the cardiovascular system. As animal experiments show this is especially clearly developed if noise occurs as an additional stress factor. The findings obtained in animal experiments may not be applied to human beings one by one as the subjective assessment of noise is of importance. An extrapolation of the results obtained by work noise studies to environmental situations is difficult. Lower noise exposures in the environmental area cause mostly stronger annoyance than higher exposures at the workplace. Also the results of laboratory investigations not covering specific vegetative reaction values may not be considered easily. Frequently data for assessing the objectiveness, reliability and validity are lacking. In particular, the investigations of the changes of the finger pulse amplitude exposed to noise are criticized. For the time being, reliable investigations proving a direct, extra-aural impairment of health by aircraft noise are not known. Indications that health risks by aircraft noise may not be excluded per se are already to be found in older investigations. Owing to acoustic data lacking they are frequently only conditionally interpretable. Yet, it was possible to derive impairment of health from available epidemiological papers on heart diseases which, however, refer only to exposure to road traffic noise. The studies show partly considerable methodical differences. There have been investigated a .o. blood pressure, ischaemic heart diseases including acute myocardial infarct etc. In Fig. 4 of the paper by Babisch in this issue the results of available studies have been compiled. The relative risk factor for persons exposed to noise is represented in the figure. In the case of the bars shifted to the right related to the relative risk of 1, means persons with a higher exposure to road traffic noise are facing a higher risk of ischaemic heart diseases as compared with persons less exposed. As the number of the bars shifted to the right shows increases of the risk were detected in most of the studies. Only in very few studies the results are statistically significant. Yet, this cannot be considered as a proof of the fact that the risk has not grown /28/. Under no circumstances there can be drawn the conclusion that the effect model would be statistically more reliable at a higher exposure as it is assumed by some authors /29/.

The available studies of the connection between road traffic noise and ischaemic heart diseases show that

- persons exposed to equivalent levels above 65 dB(A) by day show a higher risk of ischaemic heart diseases as compared with persons less exposed to an equivalent level by day below 55 dB(A).

In the case of aircraft noise there should be considered that owing to the higher annoyance effect of aircraft noise as compared with the road traffic noise and the stronger stress effect of air traffic connected with it lower values might be applicable.

Risk of impairment of hearing

In the ear mechanical energy is converted to sound waves. The sound waves produce electrical nerve impulses transmitted via the auditory nerve to the cerebral cortex. A hearing perception develops.

The proper sound transducers are hair cells (cilia) in our inner ear. In the event of the inner ear being overstrained by sound this tiny hair may be affected. If the overstrain is of a short duration and “moderate” it is only temporarily affected, temporary shifts of thresholds of hearing occur, it will be irreparably mechanically damaged in the case of an extreme overstrain, it may break. A permanent hearing loss will be caused. It may be also caused if after “moderate” overstrain resting stages will be missing.

The available papers show that

- in the case of individual rare overflights an acute impairment of the hearing is not to be expected if the maximum level will not exceed 115 dB(A) (at the ear) and the speed of level increase is below 60 dB(A) per second;
- in the case of overflights with a high speed of increase in quick succession or of a high frequency the maximum levels (at the ear) would total 105 dB(A) at most;
- in the event of a constant noise exposure permanent reductions of the hearing capacity are not to be expected (analogously to ISO 1999 /31/) if the equivalent levels at the ear of the persons affected related to an assessment period of 24 h are below 70 dB(A).

Requirements

In preparation of the revised edition of the Air Traffic Noise Act /32/ the Federal Environmental Agency formulated targets for aircraft noise control /18/. They were prepared oriented to the Federal Immission Control Act. The assessment periods were chosen analogously to the regulations on other traffic noise sources (rail traffic, road traffic). The control targets cover the following affected areas:

- aural, extra-aural health
- night’s sleep
- annoyance
- communication
- recreation.

- <u>avoiding of considerable nuisance</u> by limiting the exposure to aircraft noise (outside) to equivalent levels below **55 dB(A)** by day and **45 dB(A)** at night;
- <u>avoiding of impairment of health</u> by limiting the exposure to aircraft noise (outside) to equivalent levels below **60 dB(A)** by day and **50 dB(A)** at night.

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