National Institute for Public Health
and the Environment
*Ministry of Health, Welfare and Sport*

# The role of noise events in noise re-search, policy and practice (peaks, events or both...)

*Report of expert meeting October 25 and 26, 2010*

Letter report 815120005/2011
Irene van Kamp

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This expert meeting was commissioned by the Ministry of Infrastructure and Environment (I&M) within the framework of the Project "Health effects of environmental disturbances"

Kamp, I. van (Projectleider), RIVM

Contact:
Irene van Kamp
MGO
irene.van.kamp@rivm.nl

# Rapport in het kort

**The role of noise events in noise research, policy and practice (peaks, events or both ....)**

In opdracht van I&M heeft het RIVM in oktober 2010, een expert meeting georganiseerd over hinder door plotseling geluid (piekgeluid), en de benadering hiervan in wetenschap, beleid en in de praktijk. Doel was kennis en ideeën uit te wisselen en aanbevelingen te formuleren over situaties met kortstondige geluidpieken.

Tijdens de bijeenkomst werden voorbeelden gepresenteerd uit theorie en praktijk, bij lucht- en wegverkeer, hoge snelheidslijnen en impulsgeluid door heien en schietoefeningen. Zowel akoestische als modererende factoren kwamen aan bod, zoals de onvoorspelbaarheid van plotselinge geluiden, vertrouwen in de overheid en verwachtingen ten aanzien van toekomstige geluidniveaus. Een van de belangrijkste conclusies was dat de beschikbare relaties tussen geluid en effect gebaseerd op Lden and Lnight als uitgangspunt kunnen dienen, ook in situaties met hoge piekbelasting. Ook is geconstateerd dat aanvullende indicatoren nodig zijn die beter kunnen overbrengen wat de impact van het geluid zal zijn. In de communicatie met burgers is het van belang de hoeveelheid geluid, waar mogelijk en relevant, uit te drukken in termen die voor iedereen begrijpelijk zijn, zoals in duur, frequentie en kwaliteit. Ook het effect van maatregelen moet begrijpelijk worden gecommuniceerd: als afspraken over een beperking van geluid(hinder) niet helder naar buiten worden gebracht, zal het aantal klachten en het percentage ernstig gehinderden mogelijk stijgen onafhankelijk van de feitelijke geluidniveaus.

Het RIVM zal de aanvullende waarde en noodzaak van andere dan op decibellen gebaseerde geluidindicatoren nader bestuderen. Dit zal gedaan worden aan de hand van casestudies rond locaties met veel pieklawaai en secundaire analyses op bestaande bestanden. Met oog op de toenemende behoefte aan richtlijnen voor trillingen en piekgeluid langs het spoor, ligt de nadruk hierbij in de eerste plaats op geluid en trillingen in de buurt van hoge snelheidslijnen.

Trefwoorden: geluid, geluid maten, pieken, geluid gebeurtenissen

# Abstract


**The role of noise events in noise research, policy and practice (peaks, events or both ....)**

Commissioned by I&M RIVM organised an expert meeting in October 2010 about annoyance due to sudden noise (peak noise), and the way this is approached in science, policy and practice. The aim was to exchange knowledge and ideas and to formulate recommendations about situations with sudden high noise levels.

During the meeting examples were presented from theory and practice. Pertaining to road- and air traffic, high speed trains and impulse noise from pile driving and shooting. Acoustic aspects as well as moderating factors were discussed, such as the unpredictability of sudden noises, trust in the government and expectations about future noise levels. One of the main conclusions was that when assessing noise events and the number of events with levels above a certain maximum the available noise-effect relations which are based on average weighted measures such as Lden and Lnight, can be taken as a point of departure. Also it was concluded that additional indicators are needed in order to communicate with the public on the impact of peak events. In communications with citizens it is important to express the amount of noise, where possible and relevant, in measures that are understandable for everyone, such as events, duration and quality. Also communications about the effects of interventions should be transparent and visible: if agreements are not communicated well, the number of complainants and percentage of highly annoyed will be high irrespective of the exact noise levels.

RIVM will further study the added value and necessity of additional indicators. This will be done based on case studies around locations with peak levels of noise and secondary analysis on existing data. However, in view of increasing political pressure to devlop guidelines, focus will be in the first place on high speed trains (HSL) related noise and vibrations


Key words: noise, noise measures, noise events, peak exposure

# CONTENT

# Programme of the expert meeting

## Program Day 1: CHAIR Dr. Fred Woudenberg (Municipal Health Service Amsterdam)

11:00 - 11:15 Welcome and introduction (Irene van Kamp)

11:15 - 11:45 Martin van de Berg (VROM): Why noise indicators and how do we derive them?

11:45 - 12:15 Ric van Poll (RIVM) : Review on Peak levels.

12:15 - 12:45 Truls Gjestland (SINTEF, Norway): Aircraft noise: Is there a "correct" dose-response function?

12:45 - 13:45 LUNCH

13:45 - 14:30 AWACS CASE LIMBURG

Ric van Poll (RIVM)/Paola Esser (GGD[1] Limburg) AWACS-air traffic: health effects through peak exposures

14:30 - 15:00 Discussion

15:00 - 15:15 BREAK

15:15 - 15:45 IMPULSE SOUNDS

Joos Vos (TNO) : Human response to impulse sounds

15:45 - 16:05 Natascha van Riet (GGD Brabant/Zeeland) The impact of pile-driving in the neighbourhood

16:05 - 16:30 NIGHTTIME NOISE

Sabine Janssen (TNO): Sleep disturbance in relation to the number of noise events

16:30 - 16:45 Irene van Kamp on behalf of Lex Brown (Griffith University Brisbane): Insensitivity of traffic noise indicators to night-time heavy vehicle restrictions

16:45 – 17:30 Conclusions Day 1: major questions based on the presentations (also input for DAY 2)

18: 30- DINNER

- [1] GGD = Municipal Health Service

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## Day 2: CHAIR Dick Welkers (I&M)

9:45 - 10:15 ROAD AND RAIL

Dick Botteldooren (Uni Ghent): Modeling fluctuating noise from road and rail) .

10:15 - 10:45 Bert de Coensel (Uni Ghent) /Lex Brown (Griffith Uni Brisbane) : On the use of road traffic noise models for calculating noise event indicators

10:45 - 11:00 BREAK

11:00 - 11:20 Roel Kerkhoff (GGD Rotterdam) High Speed trains: questions about the role of peak levels in annoyance and its legal aspects.

11:20 - 11:50 Discussion

11:50 - 12:20 MIXED SOURCES

Frits van der Eerden (TNO): View on sound variations for several sources

12:20 - 13:15 LUNCH

13:15 - 13:35 Frits van de Berg (GGD Amsterdam) Noise of children: Mixed feelings regarding noise from day care centres

13:35 - 13:55 Rik van de Weerdt (GGD Arnhem) Cancelled

13:55 - 14:20 Discussion

14:20 - 14:30 BREAK

14:30 - 15:00 End conclusion (Recommendations)

15:00 -16:30 Farewell drinks

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# Background

In the scientific literature as well as in common practice we are often confronted with the question whether A-weighted noise measures are sufficient to predict effects/responses and pose a good base for noise regulation or whether we need additional indicators. Averaged noise exposure descriptors such as Lnight or Lden, say very little about the pattern of noise over time, while it might be this temporal pattern that is of particular interest in relation to perception and of concern with respect to human health.

In most cases there will be a high correlation between averaged noise exposure measures of noise and event-based measures. However, this is according to Brown (2009) not always the case and, in certain locations/and under certain circumstances this correlation breaks down. For example, around urban freight truck routes at night, the continuous overall noise levels may decrease (because ambient noise levels are low), but the identifiable number of truck peaks (loud noise events) increases.

**Aim**

To share knowledge and exchange ideas on the effects of peak levels of noise between experts from the scientific, policy and practical field.

To formulate recommendations for dealing with noise situations which are primarily dominated by noise events/fluctuations.

Examples of questions to be addressed are:

- What are the (health) effects of these peak levels?.
- Do we need to include them in our predictions of effects?
- Under which conditions and if so HOW can we do this?
- Do we need a source specific approach or can we use a more generic method?

# Proceedings of the meeting

## General introductions (Day 1)

### Welcome

The meeting is opened by Irene van Kamp (project leader and initiator of the meeting).

The main aims of the workshop are:

- To exchange knowledge and share ideas about the effects of peak levels of noise between experts from the scientific, policy and practical field.
- To stimulate the discussion between theory and practice.
- To formulate some recommendations about how to deal with noise situations which are primarily dominated by noise events.

When dealing with noise events and peak levels of noise we encounter a battle between noise measures, acute and chronic effects of noise exposure, theory and practice, relative scale of noise, producers and receivers and the issue of credibility.

The program was composed in such a way that theory and practice alternate each other, in broad lines per source or set of sources but not necessarily. In preparation of this workshop it showed how hard it was to word these aims and even to come up with a title and agree on the title. This is illustrative for the obscurities and confusions around the theme of peaks, noise events, maximum levels and single events levels. In a little opening quiz all participants agreed they had never heard an equivalent noise level and could not properly define a noise event or peak. It all depends on the context, the location, duration and background levels.

Examples of questions to be addressed are: What are the (health) effects of these peak levels, do we need to include them in our predictions of effects, under which conditions and if so, how can we do this and do we need a source specific approach or can we use a more generic method.

## Martin van de Berg: Why noise indicators and how do we derive them?

Noise indicators are often hard to understand, it needs understanding of the measuring theory behind them. Basic observations restrict the type of rules that can be applied to the integration process. The goal is to rank situations on adverseness. A parallel is drawn with EU temperature comparisons.

Lden is tested against annoyance[1] and based on frequency, description of events, a trade off factor and period of the day. The trade off factor is based on either SEL or Lmax (5-10 dBA). Several measures have been used in the past in relation to aircraft noise (NNI, KOSTEN, AN-NEI). These are noise source specific. E.g. a Trade-off factor for aircraft noise is defined for 8-13 events, for rail traffic no such relation for sleep disturbance (Lnight or events) exists. The correlations between measures are high, so therefore they are hard to disentangle. Effects found depend on the exposure response relation. Single events may produce startle effects, which are highly dependent on the rising time. The preferred measure to account for these effects in the calculation is the SEL.

There is a need for a stepwise approach and an experimental study of elements that play a role. However it is clear that Lmax is not the correct indicator to describe effects of peak level exposures.

MvdB concludes that (noise) indicators are badly needed to reduce observed data to manageable figures. By using a stepwise approach the elements can be experimentally tested. The trade off factor of 10 for events in the Leq is experimentally confirmed. Lmax is probably not the correct indicator for single events.
TvV Does not agree with this. Rising time should be determined by the time necessary to change from background noise to maximum levels (skewness of the curve). A SEL is still an average.
Comm TvV : Noise measures should be considered in relation to their aims. Which measures are adequate in regulations, rules and legal aspects aimed at protecting people. This should be reflected in the metric and also has a financial aspect. For example low frequency noise produces more annoyance in some people, but this is not adequately reflected in the noise metrics applied[2]. The same counts for a change of situations. According to TG the LAmax seems to give a better fit to protect people against aircraft noise. Lden and Lnight might be adequate measures to show the mean effects (as a proof) but we need metrics that represent what “really happens” in order to communicate with the public. So it is not the measures that the public is interested in, we are dealing with a communication issue where the total perception of the noise event (sound, sight and non-acoustical factors) is crucial. The goodness of fit in terms of correlations between exposure levels and average effects is not what interests them but rather what is good (in order to change the perception).

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[1] Reference See e.g. Miedema, Vos and de Jong, 2000 Community reaction to aircraft noise: Time-of-day penalty and tradeoff between levels of overflights J. Acoust. Soc. Am. Volume 107, Issue 6, pp. 3245-3253 (June 2000)

[2] In this specific situation the characteristics of the noise, in combination with other acoustical and non-acoustical factors, play a significant role.

Comm TG: we always come up with an indicator which will fit the data and measurements properly. We need to focus on the practicality of the indicators. JV: Maximum levels are easier to understand than SEL levels.

TG: It is about what we can measure and at the same time what people experience. There is a discrepancy between these two. E.g number of complaints related to different indicators.

HF points out that the correlation between actual levels and "claims" is low. Personal and contextual factors (often referred to as non acoustical factors) might enable us to understand this discrepancy better.

**Ric van Poll (RIVM): Review on Peak levels.**

This presentation reviews what we know about peak levels by means of presenting some examples. The first example pertains to military aircraft noise. The role of peak levels is still unclear. When Lden is associated with the percentage of highly annoyed and compare this with generalized curves we see that the number of highly annoyed is much higher. One explanation may be the number of peak levels.

Another good example are the noise levels due to high speed trains which do have a strong "peak" character.

We should pay more attention to these source specific peak levels, the exposure levels and their health effects. When we address the number of events and maximum levels per event (Lmax) we need to address the duration of the single events and the number of these events over the day as well. The Okinawa study is taken as an example where Lmax and number of events were addressed. The measure used was the TA70: referring to the time of an event above a certain level.

This is interesting in relation to the so called threshold shift which is relevant in view of hearing damage. This shift can become permanent. The Okinawa study concluded that there was a "fair chance" of permanent hearing loss in relation to time above 70 dB(A) (TAA70). The equivalent exposure levels were not significantly associated with these effects.

The last example is the experimental study of Michalde in which LAmax levels were related to blood pressure effects in relation to extremely high noise levels ("shock levels"). A sudden increase up to 75dB(A) resulted in an increase in systolic blood pressure in schoolchildren as well as heart rate changes: a decrease in HR as part of a startle reaction.

In summary: key elements are frequency of "peak level occurrence", predictability and the issue of a MALUS when the number of peak levels exceeds a certain number of events.

**Truls Gjestland (SINTEF, Norway): Aircraft noise: Is there a "correct" dose-response function?**

A general introduction on dose response curves is given. Reliable dose-response functions are important for regulatory purposes. A number of "standardized" curves is available, all based on more or less the same survey results. Large differences have been found in the "most interesting" noise interval. One could question: is there a shift in the response around DNL 55 dB. A level of 55 dB outdoors equals a level of 30dB indoors (or less). Typical maximum levels used are 45 – 50 dB indoors. Aircraft noise below DNL 55 dB is hardly noticeable. The most plausible function is one with a sudden increase around 55 dB. It is concluded that all standardized dose-response functions underestimate the response in the range LDN 55 – 65 dB. As this response is almost flat in the range LDN 55 – 65 dB, the reaction response may not be a continuous function.

Next TG presents a comparison between road and aircraft noise. During military exercises there is an increase in noise levels of 6 dB. During this time there are less civil aircrafts. This results in an increase in annoyance of 50%. It is important to communicate with the public about these military exercises: this will result in less annoyance. An example is given of a study by Nick Miller in 2001 in a wildlife area: 65dB as a cutoff level LAmax. It showed that people who were informed reported less annoyance. LAmax and number of events showed no relation. It is concluded that differences in responses to aircraft and road traffic noise seem to disappear if the noise levels refer to an indoor situation, and accounts for maximum levels. Differences in responses to noise in various settings may be attributed to differences in housing conditions (facade insulation).

Discussion: One was expecting more figures. The amount of material available to compare the different metrics is limited. Differences in sources in terms of meaning are not comparable. Also other elements play a role such as low altitude flights. It is clear that we need dose response functions for regulatory purposes, since the impacts are a fact. The standardized curves that are available are based on the same study results, but are very different. E.g. the Schultz curve is based on a synthesis of all sources, with the assumption that the effects across the sources are equal. The curves are dominated by road traffic. Energy levels versus community reaction: starts at 50-55 and a second threshold at 75 dB. For reaction an ISO standard was developed and translated in many different languages. It takes outdoor levels near the home as a point of departure (garden, balcony). Indoor we talk about 30 dB(A) and outdoors about 45-50 dB(A). There is a difference between windows open and closed. But below 55 dB noise hardly noticeable. Shift is an indicator that we do not hear in single events, so if we include the reactions below 55 we underestimate the response. A change of 2-3 dB is not an improvement since this is not noticeable. For interventions the equivalent noise metrics are not suitable. Although they are extremely easy in terms of calculations they do not take the number of events into account.

Why aircrafts are more annoying is related to the fact that we deal with separate events. The same counts for freight traffic.

LAeq: does our acoustic perception correlate with it? Refers to the ratio between maximum level per event and LAEQ. Comparing road traffic and air traffic it is shown that when we use indoor max levels the curves overlap. This proves that there could be an influence of maximum levels and suggests that we should take these into account. Other relevant aspects are insulation and housing conditions as well as location of the house (facing the road or not), types of aircrafts and types of roads. On average, the effects of interventions are not large enough to show changes in the dose response curves. The question is raised whether we should get rid of the Miedema curves or should we change the approach. Also the issue of a step-change was raised: it has been systematically shown that this results in higher annoyance levels which are persistent over time. Recent studies around major airports (Schiphol, Frankfurt) show higher noise levels and one of the hypotheses is that we are dealing with a change effect. One way to deal with this might be to come up with a new model that takes the raise in the number of events into account.

Another question raised is how we can explain the lower levels of annoyance reactions to rail noise.

It is suggested that we should show the noise levels in a way that people are used to. It might be better to show the thresholds. We assume that there is a unique relationship, but that may be the wrong assumption. It was e.g. shown in the Hyena study that there are major differences between countries in response: might be due to cultural differences, but also aspects as insulation and housing quality.

Temporal patterns should also be taken into account since we are dealing with peak levels and accompanying startle effects.

## Summary

Exposure characterization of noise is being simplified in prevailing noise metrics used as a basis for exposure response relations and this may be a pitfall: measurement data are summarized in one value and for 1 event. More events are summarized for one time period (24 hours, 16 hours etc) and more measurements are summarized in one yearly average.

There are many noise indicators available, and for annoyance it has been shown that it does not really matter which metric is chosen. For other effects, it can make a difference which metric is used. To take the number of noise events into account, LAmax is not considered a good indicator for single events, although the opinions seem to be divided on this. One of the recommendations could be to take a more practical point of view: take that metric which can be influenced. The effect of measures should preferably be part of the indicator(s) that are used. It is fro example possible that you invest quite a lot of money, while the aspect that causes the annoyance has not been taken away.
People who are annoyed are not interested in our scientific indicators but in the degree of disturbance caused by the noise: that should be a point of departure.

Communication can be considered as an important element: if promises and agreements are not kept the number of complainants and percentage of highly annoyed will be high irrespective of the exact noise levels.

A good exposure response relation is important for legal and regulatory purposes. But the responses of individual people and cases do not necessarily fit these (generalized) exposure response curves. Indoor noise levels are key in these reactions. That is why we see a strong increase at 55 dB(A) outdoors up to 65 dB(A) and after that the increase diminishes (until the next threshold at 75). Below 55 dB the indoor levels are so low that people can hardly hear it. This explains the sudden rise in annoyance at 55. Most people live in areas with noise levels between 55 and 65 dB. It is therefore suggested to exclude all events below 55 dB from the exposure response relation.

A second factor that should be taken into account is that people perceive separate noise events and not L-equivalent levels. The difference between the maximum (LAmax) levels and the mean equivalent levels (Leq) is 10-12 dB in road traffic and 15-20 dB in air traffic. This explains why people perceive air traffic noise as more annoying than road traffic noise at equal levels of LAeq.

Thirdly: Exposure response relationships represent an average at group/population level. Roughly we can expect that 50% will score above and 50% below the curve. For better understanding it is necessary to have a closer look at this, especially with respect to vulnerable groups.

# Case Studies (Day 1)

## Paola Esser: AWACS-air traffic: health effects through peak exposures

In this session the so called AWACS case was presented by Paola Esser and Ric van Poll. AWACS refers to **A**irborne **W**arning **A**nd **C**ontrol **S**ystem. It concerns military aircraft noise from a small base in Geilenkirchen, Germany, just across the border with the Netherlands. This base creates considerable disturbance and public concern in the residents. Paola addresses the health effects of these flights. The percentage of highly annoyed is high and ranges from 29% - 64%. Based on a survey in the region an exposure response relation was defined by RIVM and compared this with the curves found around Schiphol airport and the generalized curve by Miedema. In all cases there is a relatively strong association between annoyance and the Lden noise exposure. Remarkable is that the percentage highly annoyed in "Onderbanken and surroundings" is extremely high in comparison with both other curves at equal levels of Lden. Of course the noise situation is quite different than that around Schiphol. In Onderbanken it concerns only a few passages per day (apart from training days) with high peak levels", while around Schiphol we deal with a large number of passages with relatively low peak levels per individual passage. Deviation from the curve can thus be explained by these peak levels, non acoustic factors and potentially a third (unknown) factor. Since 2009 measurements have been carried out and the number of flight movements was 2975 in 2009 and the maximum number of flight movements is 3600 per year. Focus in health research has been on cardiovascular effects. (hypertension and myocardial Infarctions). A risk assessment of the health effects performed by the Municipal Health Service of Zuid-Limburg showed that with the current levels the risk for both outcomes is increased, while for other health effects this is not probable. There is still discussion about the risk of hearing damage. The maximum levels were defined as 100 LAmax (*Raad van State*) and below 110 dB(A), hearing damage is not expected. However we have to take into account how often the LAmax occurs and how long and the length of the period between flights, allowing for restoration, what type of flight has caused the exceedance, at what location has it been measured, etc etc. In other words: we need more information about the distributions of the noise events. Incidental exceedance can however be risky and lead to a so called Temporary Threshold shift (TTS) but if this happens over a longer period (in years) it is not clear what the effects would be. The problem is not restricted to the residential situation but also includes a recreational area. The main question is whether we deal with an extra risk or a negligible risk.

A contextual aspect that may play a role is the lack of control by Dutch authorities since the airbase is located in Germany. Also there has been a lot of media coverage and for safety reasons trees were cut in a recreational area. What are the public responses at the German side?

Regarding the noise metrics: LAmax may be a more suitable metric to use for this situation, but no guidelines are available on how to use this.

It may not be correct to use the exposure response curves based on Lden, because in this case, with relatively low background levels we deal with sudden shifts in noise levels.

**Ric van Poll: AWACS CASE LIMBURG**

Ric presented a perception study based on diary data among the residents of Schinveld by Reijnaerts of the Radboud University in Nijmegen. In this study 30 people participated, who filled out a diary for four days at several moments in the day. Items included were the number of perceived fly-overs, activity during fly-over, disturbance of activity, concentration, stress reactions, annoyance and aspects of vitality: irritation, relaxation, energy, fatigue, satisfaction and anxiety. LAMax levels and number of events were used to relate to diary notes. Actual measured metrics and those reported by the participants showed a fair association with the number of fly-overs, no significant association was found with LAmax. Annoyance and the number of fly-overs as well as LAmax showed a strong correlation. Concentration (as measured by the so called Bitter index) showed low correlations overall. The correlation between the several vitality scores and the number of fly-overs and LAmax was not easy to calculate since the number of cases was low. The number of flights was more strongly associated with all measured effects than Lden. The closer the different events were together the higher the % highly annoyed. Ric mentions the previously described example of Miller regarding the confounding effect of the number of events but this was not confirmed for the AWACS case. The ecological validity of this study is high with four measurement moments and sufficient recall 10 x measurements, detailed description of circumstances. It should be noted that we deal here with a events during daytime on a working day (no night or weekend flights).

The discussion focused on the uniqueness of this situation: not easy to generalize to other situations and the question is whether regulations regarding the number of flights (e.g maximum of 10 flights per day) can be used elsewhere. Also personal and contextual  factors are mentioned as relevant for this case. Potentially fear plays an important role here and the number of events could be a good indicator to map these reactions. But the key topic discussed is again whether we can use Lden as a noise descriptor here. The number of events seems to be a good descriptor here but in other studies (e.g, USA studies by Paul Schomer) this was not confirmed. The AWACS study is considered as an interesting and valuable one because it gives a good contrast with other studies: what aspects define this unique situation: more measurement and study is warranted? Potentially by including the personal and contextual factors there is more to gain than by getting stuck on the noise aspects/noise metrics. Other aspects mentioned: low frequency noise aspects and the physiological effects, which may be related to AWACS.

# Introduction Impulse sounds

### Joos Vos (TNO): Human response to impulse sounds

Joos gave a brief review of dose response relationships for the annoyance caused by shooting noise. A useful general model for predicting the expected community response was described. Moreover, experimental data on startle effects and sleeping disturbance caused by impulse sounds was presented. Finally, it was briefly shown in which way hearing loss due to impulse sounds may be prevented. Hereby the aim of the expert meeting was taken as a point of departure: temporal patterns and type of noise of artillery (impulse noise). A review of research on the annoyance caused by bangs from small firearms is presented. (Vos, 1995). Based on these studies it was concluded that for environmental assessment purposes, a penalty of 12 dB (ISO 1996-1: 2003) should be used.

A series of laboratory studies have been performed regarding a large variety of firearms. An important aspect of these was the topic of predictability. Other distinctions of importance: A versus C weighted levels, Outdoor versus Indoor.

For noise zoning, the prediction of the annoyance experienced indoors from outdoor sound levels is most relevant. In this condition the annoyance caused by the bangs from medium-large and large firearms is higher than that from small firearms. This can be explained by the smaller outdoor-to-indoor noise reduction for lower frequencies. As a result, for the prediction of the annoyance caused by shooting sounds in general, we have to take into account both the A-weighted and the C-weighted sound level. For small firearms the difference between C- and A-weighted levels is small, i.e., the additional penalty due to low frequency sounds can be neglected. For medium-large and large firearms, however, the difference between C and A may be as large as 15 or 25 dB, respectively. For those weapons, the additional penalty may be predicted from the difference between C and A. (see for details Vos, 2001)

Buchta (1983) concluded that it is more important to reduce the duration of the events rather than the number of events. This would imply that military exercises should be limited to only a part of the day. For example, shooting only in the morning period in favor of a silent afternoon.

Experiment “Schietkamp” among residents. Shooting every day for 1 hour was compared to shooting for less days but more hours per day. Whole day annoyance was expressed in Z scores. There is a preference for concentration, but one should be careful with too much concentration. An U-shape was found in the exposure response relation, which can be seen as proof that people like concentration but not too much concentration. (see references Vos et al. )

What are the implications for maximum noise levels of the above described strategy of concentration? When the above strategy is followed a bonus of 4 dB decrease is applicable with increased concentration. It is suggested to use LAeq with and without this bonus, but when you concentrate too much new solutions are necessary as compensation.

The next example JV presented, pertains to a sleep disturbance study with a specific experimental design. The aim was to compare civil impulse sounds and shooting sounds from rifles to the disturbance caused by aircraft sounds. The study was performed during nighttime. After a baseline session the exposure nights followed. Time 0 was defined by respondents. Single events and sleep: One could think of shooting sounds, aircraft landings, a door being slammed close and container noise. All these single noises give an equal chance of awakening, provided that the indoor A-weighted sound exposure level (ASEL) was equal. Often people do not wake up from 1 event but they shift into a lighter sleep level. However, for sleep disturbance the temporal aspects are extremely important: a series of events close to each other in time. For obtaining equal probabilities of awakening, the ASELs of the multiple shooting sounds (volleys) must be about 15 dB lower, and the ASELs of the multiple civil impulse sounds must be about 12 dB lower than those of the single bangs and the aircraft sounds.

Regarding the application in the field of these findings (potential to generalize) a new study would be needed to look at the effect of sensitization but currently there is no funding for that. It was concluded that for equal indoor ASELs, there are only marginal differences between aircraft sounds and single impulse events. For multiple stimuli, a penalty of about 12-15 dB seems to be needed. More research needed for understanding difference between multiple and single events, and being able to predict the degree of sleep disturbance in real situations with different temporal patterns.

# Case Studies continued (Day 1)

### Natascha van Riet: The impact of pile-driving in the neighbourhood

On behalf of Natascha van Niet, Ric presents the case study regarding impulse noise on pile driving which was performed in Eindhoven in 2009. In January 2009 the pile driving started and shortly after residents were contacting the Municipal Health service with annoyance and health complaints. After a meeting between the Municipal Health Service and the local authorities an individual approach was decided on. Pile driving has a big impact: it concerns long piles (22m) and the process is taking a long time (5 months).

A survey was performed with RIVM as advisor. During pile driving: written + telephone (V1 + T1), directly after pile driving: telephone (T2), 3 weeks after pile driving: telephone(T3) and non-response survey N= 600, distributed over 3 zone. Health issue included were noise annoyance, annoyance of vibrations, coping, self-reported health complaints (physical + mental), anxiety and the attitude towards the local government. Response rates are high and varied between 65%- 70%. Annoyance from noise and vibration is extremely high, and as expected so is concern about the health effects. The number of people with a high score on a health complaints scale was extremely high at V1 (68%) and still 22% at measurement three (T3).

Over 50% of the respondents indicated that they thought that the local government could have done more to reduce the impact. Important cause of this could be that policy makers make promises to tackle resistance, which they cannot make true in practice. Breaking promises may result in public unrest, irritation and complaints. That could be an important factor.

The high annoyance scores in Zone III maybe an effect of misclassification. Other aspects to consider in interpretation: mean age relatively high and a high number of rented homes (87%).

**For the cancelled presentation of Lex Brown we refer to the presentation and paper attached.**

**Sabine Janssen: Sleep disturbance in relation to the number of noise events**

Lnight is at EU level being used to protect people against sleep distrurbance and self reported sleep disturbance is being used as the main response (see also WHO NNGL, 2009).

The question is whether this does give sufficient protection against sleep disturbance.

Some studies (see e.g. Basner) suggest that we need the number of events as well as the single levels of events (SEL) to predict the number of awakening. Also, Passchier et al, based on the observed association between SEL and awakenings, theorized that given a certain Lnight, the number of expected awakening could still differ depending on the SEL (and therefore number) of events. Basner found that motility was a function of SEL as well as the number of noise events. It concerns individual events with a certain level in relation to the outcome (in this case sleep)

In the present study the relative impact of SEL and number of events on sleep disturbance on mean motility was investigated. It concerns secondary analysis on the aircraft sleep study data set of Passchier et al.). A difference is expected between subjective and objective sleep indicators.

Taking these findings as a point of departure this paper investigates the association between objectively measured aspects of sleep disturbance and the number of the individual noise events, based on the available data from the field study of Passchier et al. (2002). The data from this study are well suited for the present purpose, since for every subject aircraft noise exposure was measured inside the bedroom for several nights, on the basis of which both the number and the level of events could be derived. Furthermore, both subjective and objective measures of sleep disturbance were collected. The analysis focuses on mean motility during the sleep period, and addresses the question whether this motility can be predicted more accurately taking the number of passages into account that exceed a certain noise level.

Results show that motility during the sleep period was positively related with both indoor sound exposure levels and with the number of events, given a certain duration of an over flight, although number of events no longer contributed significantly when controlling for age and gender of the subject. A decrease in subjective sleep quality was found to be positively associated with indoor sound exposure levels, but not significantly with the number of events, and females overall proved to have decreased subjective sleep quality as compared to males. Results suggest that, over the whole range of exposure in the present dataset, an increase in the average sound exposure level of events contributes more to motility and to subjective sleep quality than an increase in the number of events.

Also a descriptive analysis was performed to find out whether the number of events contributes to sleep disturbance over and above the influence of LAeq level, and if so which cutoff point is critical for the contribution of number of events. The relationship becomes statistically significant with LAmax levels starting at 40dB, which in the present dataset represents 73% of the total number of events. No such evidence for a cutoff point was found for subjective sleep quality. Overall, the results suggest that, in addition to the influence of LAeq level, the number of events only influences motility above a certain level of the events, and that the influence increases with increasing levels of the events. This observation may explain why the number of events has relatively little influence when all events are taken into account.

This appears to be in contrast to earlier findings from a field study on sleep disturbance by road and rail traffic noise that quiet periods, indicative of potential restoration, might result in a change of motility during sleep. Motility was found to be higher when there is a lower percentage of quiet time, suggesting that restoration may be better when there is a concentration of events (peaks). It is not clear what we should conclude from this…..

Furthermore the issue was discussed whether these findings are meaningful to be used for noise regulation purposes. The present finding suggests that, to reduce motility as a proxy for restless sleep, it is better to prevent the occurrence of (aircraft noise) events with high maximum levels than to reduce the overall number of events.

## Discussion and conclusions DAY 1

Fred Woudenberg summarized the findings. It is clear that we have to make a distinction between acoustical and personal and contextual aspects. We need to investigate the aspects of noise events and maximum levels. Based on the presentations there seems to be a clear deviation from A weighted levels. This was shown most clearly in the findings of JV and SJ concerning sleep disturbance: The effects are not captured in a time weighted average.

Also, it was shown that the duration (time interval) between noise events is of importance: there seems to be a clear advantage to have quiet periods. Therefore we need a metric that includes quietness. In terms of noise regulation there is the choice between spreading the noise versus keeping it compact. From the presentations it is not fully clear what the preferred strategy is (if possible at all).

TG adds that this can be concluded by simple reasoning: it is clear that the number of events is relevant for responses, we cannot ignore it. However we do not know where the equivalent level ends and when we have to look at individual events, we need to define a break even point. JV points out that we do know where that level is: the number of events in combination with noise levels outside the normal range. MvdB comments that above 10 events per day, the dose response curve using equivalent metrics still looks reasonable.

How we regulate the source to protect people against aversive effects is another story. It is commented (Theo) that regarding aircraft noise insulation protection is not working. How do we explain that? This is a discussion between exposure response curves and noise abatement. DB: Laeq is good within a certain range. When you move (as is the tendency) to the edges of the range what will happen in the future?

Key elements seem to be the number of events, the higher noise levels and temporal variation. These are sometimes referred to as non acoustical factors, but to be distinguished from non acoustical factors at personal, social and contextual level. On top of that and complicating things further, is the large influence of these other personal and contextual factors. Partly these can be dealt with by communicating better about expected noise levels so people know what to expect. This could be done based on the generalized curves.

# General introductions (Day 2)

### Dick Botteldooren: Modelling fluctuating noise from road and rail

An overview is given by Dick of the modeling work performed at the University of Ghent around the perception of fluctuating noise of rail and road traffic. A vision is given about peak noise of road traffic and train noise. A distinction is hereby made between (threshold) continuous levels versus peaks. Three generations of perception models were presented. The 1st generation model presented accounts for a trade-off between events (comparable with what Truls Gjestland presented). The model takes into account effects of insulation and activity patterns. JV remarks that this implies a shortcoming: one should address the issue of spectral content. Dick indicates that the first generation model does not take spectral effects in to account.

The 2nd generation model accounts for the spectral-temporal structure of the noise, and thus considers effects of tonality and rise times, for which only using A-weighted sound pressure levels is not sufficient. Salience of sound events is a key concept, referring to peaks in the sound wave that are conspicuous and thus will draw attention. The 3rd generation model, which is still under development, models auditory scene analysis in more detail.

An example application of the first generation model is presented, considering a sample of 7500 locations in Flanders. Assumptions were made about background noise levels. (A model for the perception of environmental sound based on notice-events J. Acoust. Soc. Am. Volume 126, Issue 2, pp. 656-665, August 2009). Key concept in the model is the concept of notice-events. The applicability of the notice-event model is illustrated by simulating a synthetic population exposed to typical Flemish environmental noise. From these simulation results, it is demonstrated that the notice-event model is able to mimic the differences between the annoyance caused by road traffic noise exposure and railway traffic noise exposure that are also observed empirically in other studies and thus could provide an explanation for these differences.

The second example pertains to the ALPNAP study (Peter Lercher), concerning a questionnaire survey in the Brenner region. In a logistic regression model Lden came forward as an important predictor of response. It was shown that 1 noise source overruled the other. A clear change of peaks was observed at the quiet side of the dwellings. Potentially more loudness but fewer peaks.

A distinction has to be made between epidemiological studies versus studies into the mechanisms. The former result in black-box models that do not really explain the underlying mechanisms. The proposed approach is an example of the latter. The final goal of the presented approach is to build a "unified theory", which accounts for noise from different sources on an equal basis. The basic assumption hereby is that differences in the perception between different sources (e.g. road and railway traffic) are mainly caused by differences in spectral and temporal structure (e.g. statistical properties), and that the informational content of sources (e.g. the green image of trains) only plays a minor role in the perception.

**Bert de Coensel: On the use of road traffic noise models for calculating noise event indicators**

Current traffic noise prediction models are designed to estimate long-term equivalent noise levels, but are not able to take into account the temporal pattern of the sound pressure level. Several models have recently been developed, mostly for research purposes, which are able to estimate the temporal pattern of road traffic noise, and which can therefore be used as a tool to calculate noise event indicators. Bert De Coensel gives an overview of the model that was developed at Ghent University.

The DIPSIR framework is taken as a reference to explain the different parts. The model consists of a coupling of a microscopic traffic simulation model (which simulates the movements of individual vehicles), an instantaneous noise emission model (the Harmonoise/Imagine model which takes instantaneous speeds and accelerations as input), and a beam-tracing propagation model. Important inputs for the model are the traffic demands, the composition of the traffic, location of buildings etc.. Activity patterns could be incorporated into the model.

This very detailed approach is gaining ground as computational resources are increasing, but a disadvantage is that simulated road networks need to be calibrated extensively, which can be time-consuming for larger networks. This modeling approach could e.g. be used to give a more precise fit for the evaluation of sound barriers or other interventions (changing road surface, installing traffic management measures etc).

For the estimation of the impact: which indicators should be used? The following requirements are mentioned: The indicators have to be (EU Noise Indicators, EC Working Group 1 on indicators):

- Valid: scientifically proven relation with considered noise effect
- Applicable: relatively easy to measure or compute
- Transparent: intuitive and easy to explain
- Enforceable: possible to easily find out if limits are exceeded
- Consistent: strong deviation from current practice only if it is significantly better.

The model simulates the time-varying sound pressure level in 1/3-octave bands. The current implementation does not simulate the sound waveform itself, because this would be too computationally demanding. The main field of application of this model is to investigate the impact of traffic management measures. Validation results show that peak levels can be estimated reasonably well, but the model performs worse for estimating background levels (as they are often caused by distant sources or sources that are not road traffic related). Additionally, it was shown how the model can be used to account for different driving styles, and how meteorological effects can be accounted for within the propagation model. BdC comments that the model can be used to estimate average sound pressure levels.

Several case studies and research applications are presented (some of them in collaboration with TML Leuven and TNO): e.g. a comparison of Lden and L50 for characterizing "quiet" areas, and a study on the influence of vehicle acceleration near intersections on sound levels.

Preliminary results of simulations in the framework of a joint project with Griffith University (ARC Linkage project) were presented, considering the correlations between traffic flow characteristics and peak level metrics. The effects of increasing traffic flow on the presence of individual peaks and quiet periods was illustrated.

## Case studies (Day 2)

**Roel Kerkhoff (High Speed Trains): Questions about the role of peak levels on annoyance and its legal aspects**

RK presented a practical example of peak levels of HST and accompanying legal and regulating aspect. No community response studies have been performed yet. This case concerns the Schiphol – Antwerpen line near Lansingerland. Immediately after this line became operational many complaints reached the local authorities (DCMR). For the total area (50-300 meter) an information evening was organized where people could ask questions about annoyance, real estate values (and changes in this) en action groups. There was a lot of public commotion in L. and not elsewhere. This was a clear example of a change situation also a change in sound dampening measures, working as a sound-box (klankkast). The old material used in the beginning gave more noise due to peaks and rising speed. These peak levels were not taken into account. Re. regulations: according to RK the Dutch law on noise annoyance does not include peaks, since these are not sufficiently included in the Lden.

There is no dose response curve available for HST and the generalized relation of Miedema is not applicable. In Dutch noise regulations a train is a train: no distinction is made.

For the Miedema curves shunting yards were taken as comparison. The difference in the number of complaints may be a change effect. The Intensity of the rail traffic is still not operating to its full capacity. Expectations may play an important role as well: again the role of personal and contextual factors is mentioned as potential explanation of the strong reaction.

TG comments that internationally a train is not a train. A correction factor (see ISO) is applied in terms of a MALUS and BONUS dependent on the characteristics: tonality, etc. The same could be applied to military aircraft noise (AWACS) in terms of penalties and limit value.

Based on data available it was shown that the closer to the track the better the fit. This is good news for the model of Dick Botteldooren: it has been shown that distance is indeed a very important predictor.

Aspects of sound and vibration are also mentioned especially near Eindhoven. The trains are with 160 km not much faster than normal trains. There might be something else playing here: If you look at Miedema's study on fear and NS this explains the rail BONUS. However: in high speed trains the sound rises more steeply (although not as extreme as in earlier days): so the new element might be fear again and this is also related to distance. People describe the sounds as if a container is being emptied. We are dealing here with an extreme case comparable with the AWACS case. Possibly there is an effect of the structure of noise.

Again the question is raised whether Lden is useable?

Whether the noise resembles industrial sound < high pitched tones> .

This specific case showed that communication has its limits and the temporary noise situation (due to the use of old materials etc) clearly was very powerful in setting the tone. In this case a model would not work: Trust between GOV and citizens had already been damaged.

**Frits van der Eerden: View on sounds variations from different sources**

Making use of 4 cases the issue of perceived sound *variations* is presented. They pertain to real life situations. Background for these exercises was that the complaints of residents were not related to Lden levels.

These 4 cases show that it is possible to look into the actual variations of perceived sound. By using measurements and numerical techniques it is possible to visualize the sound variations. Next, these details may contribute to the development of a more suitable noise indicator. Or more generally, by providing input for the development of new policy and communication with the community.

The 4 cases are:

- Industrial noise (Maasvlakte – Oostvoorne)
- Aircraft noise (Ground-noise - Hoofddorp)
- Impulsive noise (Shooting noise)
- Traffic noise (Monitoring in Breda)

*Case 1: Oostvoorne (view on sound) – water-land interfaces*

Industrial noise from Europoort/Maasvlakte is heard in Oostvoorne, a few kilometers away. The amount of complaints is relatively high there.

Within the 'Geluid in Beeld' project, TNO investigated the variation of sound due to meteorological variations. The meteorology is complex in that area due to a complex composition of water and land surfaces (and a lake in between). A meteorological-acoustical model is used to provide insight in the variation of the sound levels. It also provides the possibility to forecast the sound situation.

Detailed complaints were recorded for a number of months. It was found that complaints are expected for high sound levels as well as for increasing sound levels. It is therefore concluded that Lnight en Lden are 'limited' measures; variations in sound levels are also important.

*Case 2: New runway "Polderbaan" 2003 (Schiphol)*

With the realization of a new runway for the Amsterdam Airport Schiphol, there is an increase of complaints in Hoofddorp. The distance between the runway and Hoofddorp is about 3 km. The departing and landing noise from the aircraft was found to be the dominant source, especially for low frequencies (in the 31 Hz band). It was found that for certain days there is an increased level (mostly during winter time).

By considering the meteorology, as well as the ground absorption, it was demonstrated (by means of ground measurements, a meteo-acoustic model and visualization techniques) how increased sound levels occur: for a downwind situations and a relatively hard ground (via multiple ground reflections). These hard ground conditions occur in the winter time when there is no crop on the field an the ground is saturated with water.

Next, the possibility to reduce the occurrence of these high sound levels was investigated. The effect of multiple ground reflections can be reduced via an increased ground absorption and/or by a geometry (objects or the ground itself) that scatters these reflections.

*Case 3: Shooting Noise*

The variation of perceived shooting noise levels, for a distance not close to the source, is large. Even during a short period of time (within minutes) differences of more than 10 dB can occur in the perceived sound level from repetitive events from the same source.

As an annoyance–related measure, the long-term-average rating sound level is used. It has a penalty of 12 dB for the impulsiveness. In a newly proposed method the meteorology statistics for the Netherlands are incorporated (for the sound propagation). By adding the meteorology (and the ground absorption) one can get a distribution of sound levels for the purpose of environmental assessment. For instance, the average level can be used for environmental permit, but the distribution indicates that there will be levels below and above this average.

A special case was shown for impulsive noise in the Wadden-eilanden area (Wadden islands). Here, the ground and meteorology (and therefore the sound propagation) differs from the average Netherlands situation. Therefore a meteorological-acoustical model was applied. Large differences with the standard Dutch method (HMRI) were found.

*Case 4: Road traffic noise*

Traffic noise is a major source for annoyance, The effect of changes in traffic management, applying mitigation measures or changing policies, can be seen directly when the actual noise situation is monitored. It is argued that a ‘model-based monitoring’ technique has to be applied; a combination of measurements and calculations. Via measurements the actual noise levels are obtained, via calculations the actual noise levels are available ‘everywhere’ and the calculations can be validated with measurements. Also, when a model is used prognoses can be made. Moreover, the debate on measurements or calculations (for aircraft noise, for instance) is neutralized.

By monitoring the actual sound variations will be captured. These can be used for the development of for instance new noise indicator. A sensor network with microphones has been applied in neighborhoods in the city of the Hague and Breda.

Overall conclusion: Sound and noise variation are the main reason for complaining. This was shown by presenting examples from various sources: Industry / ground-noise of aircrafts at take-off / Shooting noise / Traffic noise

We need methods and tools to show (and visualize) these variations, which can be used for a better environment / a better indicator / better policy making / better communication.

**Frits van den Berg: Noise of children: Mixed feelings about noise of day care centres**

Human voices lie somewhere between mechanical and natural sounds.

Aspects that play a role are:

- Meaning of the sound
- Mood of the listener
- Location (at home, outdoor, work)
- Time of day (day/ night)

Jastreboff (1990) has presented a neurological model for perception and evaluation of sound (for tinnitus) This model could be valid for all sound perceptions. According to this model a negative evaluation of the sound enhances its perception reinforcing the evaluation.

One effect of 'noise' is (self reported) annoyance: at low levels some people are annoyed, but even at high levels some are not (Miedema and Oudshoorn 2001). A large group is not (highly) annoyed by the outdoor sounds of day care centres. So clearly not only acoustical factors play a role but also aspects as housing, area, social cohesion etc. and individual factors (as opposed to group level factors). There have been several changes regarding the regulation on daycare centres implying that more noise is allowed and most noise is actually excluded from regulations. Nevertheless we are dealing with extremely high levels in day care centres (see e.g. Maxwell and Evans 2000) and high outdoor levels.

The effects are related to sound level, but also to the types of noise: screams and crying of children/scraping of chairs and other objects. When studying this type of noise several aspects have to be taken into account:

- (average?) façade sound level
- time of day
- indoor level/insulation
- quiet side
- background sound level/other sources
- quality of dwelling and neighborhood
- appropriateness of source in area
- relation to noise source
- fair balance of interests
- 'individual' factors: fear, noise sensitivity, age, health status

Preschool teachers have a vocally strenuous profession (Södersten, et al, 2002). Speaking during their work is on average 9.1 dB louder and at higher frequencies (202 -247 Hz). Sound levels (73–78 dBA) are higher than recommended for speech communication (50–55 dBA). Daycare centres have to provide access to an outdoor play area. In terms of occupational noise: primarily behavior (of the children) related. TG comments that day care centres are the same in Norway and definitely above the safety limits of occupational noise so it needs strict regulations. However, the Norwegian Law assessing technical sound also excluded sounds produced by children. An experiment was carried out in Norway in which the children were taught to reduce their sounds by using a monitoring system (Green, yellow and red lights indicating the sound levels). This is a playful application of the limits ('acoustic education'). This is easier to do indoors than outside. A dose response relation is not available for this type of noise.

Finally **Danny Houthuijs**[3] comments on the presentations on Awacs: he warns against jumping to conclusions too quickly regarding the noise issue in Geilenkirchen. Then a discussion follows about the noise metric to be used and which one is most fit to compare with other airports (civil) such as Schiphol where most flights ate below the NA80 level. It is commented that it does not really make a difference what indicator you use: with a certain x variance around a given value you always find variance of response. Because there is an association between Nax and Lden you do not find a difference (see earlier: high correlations between metrics) For example see the study of Basner in relation to sleep disturbance (events). You actually see more effect of Lden according to Danny.

In summary (from sheets)
Consequence of high correlations between Lden and events (aircraft) is that we can easily switch from dose response relations for Lden to dose response relations for NAx: this is more transparent for lay people. However, the dose-response relations from Geilenkirchen and from Schiphol differ substantially when expressed in NAx, since the exposure difference in NAx is much larger than in Lden.
There is no indication that for an airport the use of NAx has (much) additional value to predict annoyance in the case that Lden is present.
Limitations of the AWACS study:

- Only 2 airports
- No other indicators used (NA80, time above etc) and evaluated
- Data driven results

Danny doubts whether Geilenkirchen can be considered as an extreme case with respect to the impacts of events on the dose response relation. Can we justify dose response relations for NAx for policy makers and airport operators given their difference? Some doubt this because NAx is not qualified as a good indicator.

[3] Full presentation not included because this is unpublished work

# Final Conclusions and recommendations

The presentations and discussions during this meeting covered a broad range of issues related to noise events, peak levels of noise from a scientific, policy and practical perspective. The combination of theoretical and practical presentations did indeed stimulate the discussion between theory and practice. From this, a set of points of attention can be derived, although we are still far away from formulating harmonized conclusions and recommendations.

A clear gap shows between theory and practice: e.g. previous results of an experiment have shown that the responses to HST and regular trains are highly comparable. However, the opening of a new High Speed line in the Netherlands showed considerable community responses and also pointed out that Lden based exposure response relations do not fit the annoyance due to the noise from high speed trains. In this acoustic as well as non-acoustic aspects may play a role, but this has not been adequately studied yet. Also in the examples regarding aircraft noise and impulse sounds comparable discrepancies were mentioned in the discussion, but in most cases not verified.

Acoustical factors that are relevant with respect to peak noise are: frequency of “peak levels”, the issue of a MALUS when the number of peak levels exceeds a certain number of events, meteorological conditions, variation of sound level, time aspects, activity patterns, distance to the source, housing conditions (facade insulation), indoor noise situation versus outdoor, maximum levels, the combination of number of events and maximum levels and duration of events rather than the number of events. It is concluded that differences in responses to aircraft and road traffic noise seem to disappear in an indoor situation and when maximum noise levels are taken into account. Differences in responses to noise in various settings may be attributed to differences in housing conditions (facade insulation).

**Main messages**

When assessing noise events and the number of events with levels above a certain maximum we should still take the available exposure response curves, which are based on average weighted measures such as Lden and Lnight, as a point of departure. However, we need other approaches and ways of visualization to communicate with the public on the impact/perception of peak events. Some general conclusions and accompanying recommendations are:

- The focus in noise regulation is now on threshold levels, but a focus on periods of quiet could be just as important. Quiet periods or a quiet side at the home can compensate for noise up to 8 dBA.
- The background level determines effects of peak sounds. This can be dealt with by using a MALUS in a quiet background.
- Tonal components have large effect. Tonality can be used as an effective measure to decrease annoyance.

- We do not know yet at what point we should shift from using average levels (Laeq) to noise levels of single events. Depending on other factors as well, the limit is assumed to lie somewhere around ten events. Below ten events, equivalent levels may be less relevant.
- Temporal variations have to be included in the modeling, because they may reduce thresholds of awakening and other effects on sleep and because single sounds can have a startle effect.
- All models work fine for regulation goals, but not for understanding and dealing with individual cases. Aspects that additionally play a role are recovery and restoration, the richness of specific noise situations and personal and contextual factors like the predictability of the noise, trust in government and expectations.
- When studying the additive value of situational aspects such as noise events and maximum levels comparisons should preferably be made between locations and groups and not within single studies given the high correlation between noise indicators at one study location.

In view of the commotion after the new High Speed Train track came into service in the Netherlands as well as cargo transport by rail at night is increasing, the political pressure is large for additional norms for peak noise. In the framework of this, RIVM has been asked to describe the requirements and conditions for a study into the (health) effects of peak-noise and vibrations. The methods and models as presented at the expert meeting will be very valuable. They will be applied in several case studies in which peak noise plays a dominant role.

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# ANNEX 1: PARTICIPANTS

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|---|---|
| Truls Gjestland (TJ) | SINTEF Trondheim |
| Dick Botteldooren (DB) | University Ghent |
| Bert de Coensel (BdC) | University Ghent |
| Frits van der Eerden (FE) | TNO |
| Sabine Janssen (SJ) | TNO |
| Ric van Poll (RvP) | NL institute Public Health and the Environment |
| Joos Vos (JV) | TNO |
| Martin van de Berg (MvdB) | Ministry for Infrastructure and the Environment |
| Paola Esser (PE) | Municipal health Service ZuidLimburg |
| Roel Kerkhoff (RK) | Municipal health Service Rotterdam |
| Natascha van Riet | Municipal health Service Brabant en Zeeland |
| Frits van den Berg | Municipal health Service Amsterdam |
| Fred Woudenberg (FW) | Municipal health Service Amsterdam |
| Dik Welkers (DW) | Infrastructuur en Milieu |
| Hendrik Faber (HF) | Ministry of Defenses |
| Roel Hogenhuis (RH) | NLR |
| Theo van Veen (TvV) | NLR |
| Dick van der Gugten (DvG0 | V&W |
| Rogier Wigbels (RW) | DCMR |
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| Eric Schreurs (ES) | NL institute Public Health and the Environment |
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| Danny Houthuijs (DH) | NL institute Public Health and the Environment |
| Irene van Kamp (IvK) | NL institute Public Health and the Environment |
| Annelike Dusseldorp (AD) | NL institute Public Health and the Environment |
| Joost van der Ree (JvdR) | NL institute Public Health and the Environment |
| Miriam Weber (MW) | DCMR |
| Joop van Engelen (JvE) | NLR |

# Glossary of terms used in noise control

Based on the Position paper on EU noise indicators, August 27, 1999 page no. 68)

**Noise**

Noise is sound which has a negative effect on people. (Unwanted sound.)

**Sound**

Sound refers to physical vibrations transmitted through the air which are audible to people.

**Annoyance**

Annoyance is a term used to describe the negative feelings associated with noise. Annoyance is annoyance reported using a particular scale and therefore has a precise meaning in terms of that scale.

**Sleep disturbance**

Sleep disturbance can be defined objectively in a number of different ways ranging from the smallest detectable physiological response to some external stimulus whilst asleep to actual behavioural awakening. Sleep disturbance can also be described subjectively using some appropriate scale after the event. If there are any effects on mood, attitudes or performance of some task the next day, such variables could also be measured, both objectively and subjectively.

**Speech interference**

Speech interference can be defined objectively by measuring the proportion of utterances heard incorrectly, or subjectively in terms of a listener's general impressions of the amount of speech incorrectly uderstood. Speech interference is not the same thing as message intelligibility which can be quite good even where there is significant speech interference because of the redundancy in normal speech.

**Complaints**

Complaints describe any kind of written or spoken negative observations which are made to authorities and which are recorded in such a way that statistics can be kept. Informal complaints which are not recorded are of limited value in environmental noise assessment.

### Long term health effects

Long term health effects can be defined as abnormal adaptations of the human body to environmental stimuli. These might include cardiovascular, immune system and mental health effects, although the extent to which there may be a causal relationship with excessive exposure to environmental noise remains subject to scientific debate.

### European Environmental Noise Indicator

This is the harmonised system of basic and supplementary descriptors of the physical

magnitudes of environmental noise for use in different situations, as defined in the Framework Directive on Environmental Noise.

### Sound power

This is defined in ISO 31-7: 1992 'Specification for Quantities, units and symbols, Part 7. Acoustics' as '*Power emitted, transferred or received as sound waves*'. Sound power is

given the symbol *P*, and measured in watts (symbol W). The unit of sound power is a

derived SI unit as defined in ISO 1000: 1992 'SI units and recommendations for the use of their multiples and certain other units'.

### Sound intensity

This is defined in ISO 31-7: 1992 'Specification for quantities, units and symbols, Part 7.

Acoustics' as '*For unidirectional sound power, sound power through a surface normal to the direction of propagation divided by the area of the surface*'. Sound intensity is given the symbol *I*, and measured in watts per square metre (symbol W/m2). The unit of sound intensity is based on the derived SI units for power and area defined in ISO 1000: 1992 'SI units and recommendations for the use of their multiples and certain other units'.

**Sound pressure**

This is defined in ISO 31-7: 1992 'Specification for quantities, units and symbols, Part 7. Acoustics' as the '*Difference between the instantaneous total pressure and the static*

*pressure*'. The static pressure is defined as the '*Pressure that would exist in the absence of sound waves*'. Sound pressure is given the symbol *p*, and measured in pascals (symbol Pa). One pascal is a pressure of one newton per square metre. The unit of sound pressure is a derived SI unit defined in ISO 1000: 1992 'SI units and recommendations for the use of their multiples and certain other units'.

**Peak value**

This is the maximum instantaneous value of any variable quantity occurring within a defined observation time period. The peak sound pressure is the maximum instantaneous sound pressure occurring within a defined observation time period.

**Maximum value of the short time exponential average root mean square sound pressure using F detector-indicator characteristic**

This is not the same as the peak value which is the maximum instantaneous sound pressure without averaging of any kind. The peak sound pressure can be positive (above the static atmospheric pressure) or negative (below the static atmospheric pressure). The maximum value of the short time exponential average root mean square sound pressure using the F detector-indicator characteristic (see BS EN 60651:1994 (IEC 651:1979) 'Sound level meters') is usually more closely correlated with the short term subjective loudness of the sound event than the peak sound pressure.

**Decibels**

In environmental noise, decibel measures (symbol dB) are commonly used in any one of three different ways. The decibel is essentially an indicator of the ratio between two energy or power quantities expressed in powers of ten (this requires the use of logarithms). Each decibel is one tenth of a Bel. The number of Bels is the ratio expressed as powers of ten.

**Lmax, maximum sound level**

The maximum sound level is the maximum value of the short time exponential average root mean square sound pressure using the F detector-indicator characteristic expressed in decibels.

**L , average sound level eq**

The average sound level is simply the long time linear average root mean square sound pressure expressed in decibels. It is sometimes defined as the Equivalent Continuous Sound Level because the Leq of a fluctuating sound has the same numeric value as a completely steady sound with the same acoustic energy over the same observation time period. The average sound level over a defined time period is not the same as the average of the separate maximum sound levels of a sequence of events occurring within the same observation time period.

**Statistical indicators**

Various statistical indicators such as the L10 and the L90 have been adopted for particular purposes in the past. The Ln series of statistical indicators are defined as the sound level which is just exceeded for n percent of the defined observation time period. All such indicators are effectively obsolete for present purposes.

**Frequency spectrum**

Frequency is measured in hertz (symbol, Hz). The explanation given in ISO 31-7:1992 'Specification for quantities, units and symbols, Part 7. Acoustics' is as follows: '*1 Hz is the frequency of a periodic phenomenon of which the period is 1 s*'.

**A-frequency weighting**

The A-frequency weighting is defined in BS EN 60651: 1994 (IEC 651: 1979) 'Sound level meters' in terms of the relative free-field frequency response of the sound level meter to sounds incident from the defined reference direction for that particular instrument, expressed in decibels of attenuation relative to a frequency around the middle of the auditory range (1000 Hz).

**NAx**: number of events above level x.

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