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

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ABSTRACT

Commissioned by the Netherlands Ministry of Infrastructure and the Environment RIVM organized an expert meeting about reaction to sudden noise, and the way peak noise is dealt with in science, policy and practice. The aim was to exchange knowledge and ideas and formulate recommendations about situations with sudden high noise levels. 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 and moderating factors were discussed, such as unpredictability; trust in the government and expectations about future exposures. The main conclusion was that in most cases available noise-effect relations based on average weighted measures (Lden, Lnight) can be used. Additional indicators are primarily needed to better communicate with the public on the impact of peak events; noise exposure levels, where possible and relevant, should be presented to the public in understandable measures such as events, duration and quality as well as the effects of interventions. When not communicated well, the number of complainants and percentage of highly annoyed will be high irrespective of the exact noise levels. This paper presents the highlights of the workshop, and more recent findings in relation to military air traffic and the role of peak levels on registry based health effects.

Keywords: noise, noise measures, noise events, peak exposure
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1. INTRODUCTION

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 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.

Commissioned by the Ministry of Infrastructure and the Environment (I&M) RIVM organized 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 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. 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 of the workshop was composed in such a way that theory and practice alternate each other, in broad lines per source or per set of sources, but not necessarily. In the preparation of this workshop it already 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 the main questions addressed were:

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

Along these lines this paper will summarize the different papers which were presented at the workshop, subdivided in a theoretical and practical part. Since the workshop, RIVM addressed the question of added value and necessity of additional indicators in several studies and based on data from studies around locations with peak levels of noise and secondary analysis on existing data: the AWACS study. This paper presents a synopsis of the presentations and discussions at the workshop and summarizes the latest insights in relation to (military) aircraft noise.

2. PRESENTATIONS: Theoretical

2.1 Summary [Based on paper 1, 2 and 3)[1] [2] [3]

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. However, 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 onthis. 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 for 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 and therefor 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?

[1] Martin van de Berg (NL GOV): Why noise indicators and how do we use them
[2] Ric van Poll (RIVM): Review on Peak levels.):
[3] Truls Gjestland (SINTEF, Norway Aircraft noise: Is there a “correct” dose-response function]

2.2 Summary (Based on papers 4 and 5) [4] [5]

An overview is given by Dick Botteldooren of the modeling work performed at Ghent University. 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 to what was discussed in paragraph 2.1. The model takes into account effects of insulation and activity patterns. 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. 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. It was 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 with potentially more loudness but fewer peaks. The final goal of the presented approach is to build a “unified theory”, which accounts for noise from different sources on an equal basis assuming 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. Current traffic noise prediction models are not able to take the temporal pattern of the sound pressure level into account.

Bert De Coensel gave subsequently an overview of the model that was developed at Ghent University. The DIPSIR framework (EEA, 1999) is taken as a reference to explain the different parts. The model links 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 also 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). 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.

[4] Dick Botteldooren: Modelling fluctuating noise from road and rail;
[5] Bert de Coensel: On the use of road traffic noise models for calculating noise event indicators

2.3 Summary [6]

Joos Vos 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 was 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.

3. PRESENTATIONS: Case studies

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

On behalf of Natascha van Niet (Municipal Health Service) Ric presented 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 starting to contact 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 were high and varied between 65%- 70%. Annoyance from noise and vibration was extremely high, and as expected so was 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). An explanation for the extremely high levels of annoyance could be the (primarily negative) perception people had about the local government’s role.

3.2 Paola Esser and Ric van Poll: AWACS-air traffic: health effects through peak exposures

Paola Esser and Ric van Poll presented the so called . AWACS study, which refers to Airborne Warning And Control System. 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.. 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 was 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 from 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. Regarding the noise metrics:it was concluded that LAmax might be a more suitable metric to use for this situation, but no guidelines are available on how to use this. It may be less suitable 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.

The second part of the presentation pertained to a perception study based on diary data among the residents in the area around the military airport. 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

[6] Joos Vos (TNO): Human response to impulse sounds

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. 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. The confounding effect of the number of events as described by Miller (ref) 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 key topic discussed in relation to this case was whether we can use Lden as a noise descripton. The AWACS study is considered as an interesting and valuable case 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.

It was commented that we should be careful with 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. 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: 1) Only 2 airports. 2)No other indicators used (NA80, time above etc) and evaluated 3) Data driven results. One 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. (Houthuis et al, 2012)

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

Lnight is at EU level being used to protect people against sleep disturbance 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 et al, 2010) 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, jrtal) 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., 2002). 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. 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. 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. (see also Janssen et al, 2014 in press)

3.6 Roel Kerkhoff (High Speed Trains): Questions about the role of peak levels on annoyance and its legal aspects for calculating noise event indicators

Roel Kerkhoff presented a practical example of peak levels of High Speed Trains (HST) and accompanying legal and regulating aspect.. 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 one municipality (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. Also the old material used in the beginning resulted in more noise due to peaks and rising speed. No community response studies have been performed yet in the Netherlands regarding HSPT and so 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 considered as a train: no distinction is made (however at international level such a distinction is made: A correction factor (see ISO) is applied in terms of a MALUS and BONUS dependent on the characteristics: tonality, etc. When 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; people described the sounds as if a container is being emptied. We are dealing here with an extreme case and again the question is raised whether Lden is the most suitable noise measure: The sound might actually be more comparable with industrial sound with high pitched tones. Exposure response associations taking these characteristics into account should be further studied. 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"(read attitude).

3.7 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 were:
- Industrial noise (Maasvlakte – Oostvoorne)
- Aircraft noise (Ground-noise - Hoofddorp)
- Impuls noise (Shooting noise)
- Traffic noise (Monitoring in Breda)

Case 1: 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: 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). Aspects as ground absorption as well as meteorological circumstances showed to play an important role, which do not show up in average weighted sound models.

Case 3: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.

Case 4: The last case pertains to road traffic noise: 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.

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

Sound levels at preschools are primarily linked to human/children’s voices, and noise resulting from contact with materials: scraping sounds of chairs etc. No dose response relations are available for this type of noise 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
- personal factors: fear, noise sensitivity, age, health status

3.9 Discussion and main conclusions of the workshop

One of the end conclusions of the workshop was that we need to further study the added value and necessity of additional exposure indicators. One of the main conclusions of the meeting 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.

4. New Insights

4.1 Concern about peak noise due to military aircraft noise (AWACS)

In the past two year a study was performed around the military airport in the south of NL. The reason for this study was increasing concern among members of the Commission AWACS Limburg (CAL) and the Dutch parliament in response to results of an investigation by the Municipal Health Service South Limburg, and recent results of international studies. In particular, there was concern about the long-term exposure to (peak) sound from military aircraft on well-being and health of the population in the Dutch region around the airbase Geilenkirchen. .Ample attention was paid in this study to the association between different exposure measures and survey and registry health data with underlying question whether the effects are solely related to sound levels or peak loads. The noise exposure was described with integrated noise metrics such as Lden and Ke (Kosten Eenheden). In addition, RIVM used noise indicators that describe specific characteristics of the sound such as the highest sound level of the noise event (LAmax), the duration of the noise event (TAx) and the number of noise events (NAx). However, the association of these metrics with severe annoyance and other health endpoints was not stronger than the association with Lden or Ke[7]. The A-weighting (dB (A), compared to the C-weighting, appears to be sufficient to characterize sound of AWACS. Health endpoint addressed included registry data regarding mortality due to natural death, cardiovascular disease, ischemic heart disease, acute Myocardial Infarction, stroke and heart failure. (RIVM, van Poll ed, 2014, in press).

5. END CONCLUSION

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).

[7] Noise exposure in Kosteneenheden (Ke) is a unit in which the main factors determining annoyance due to air traffic noise are accounted for (comparable with ANEI, and NNI)

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.

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