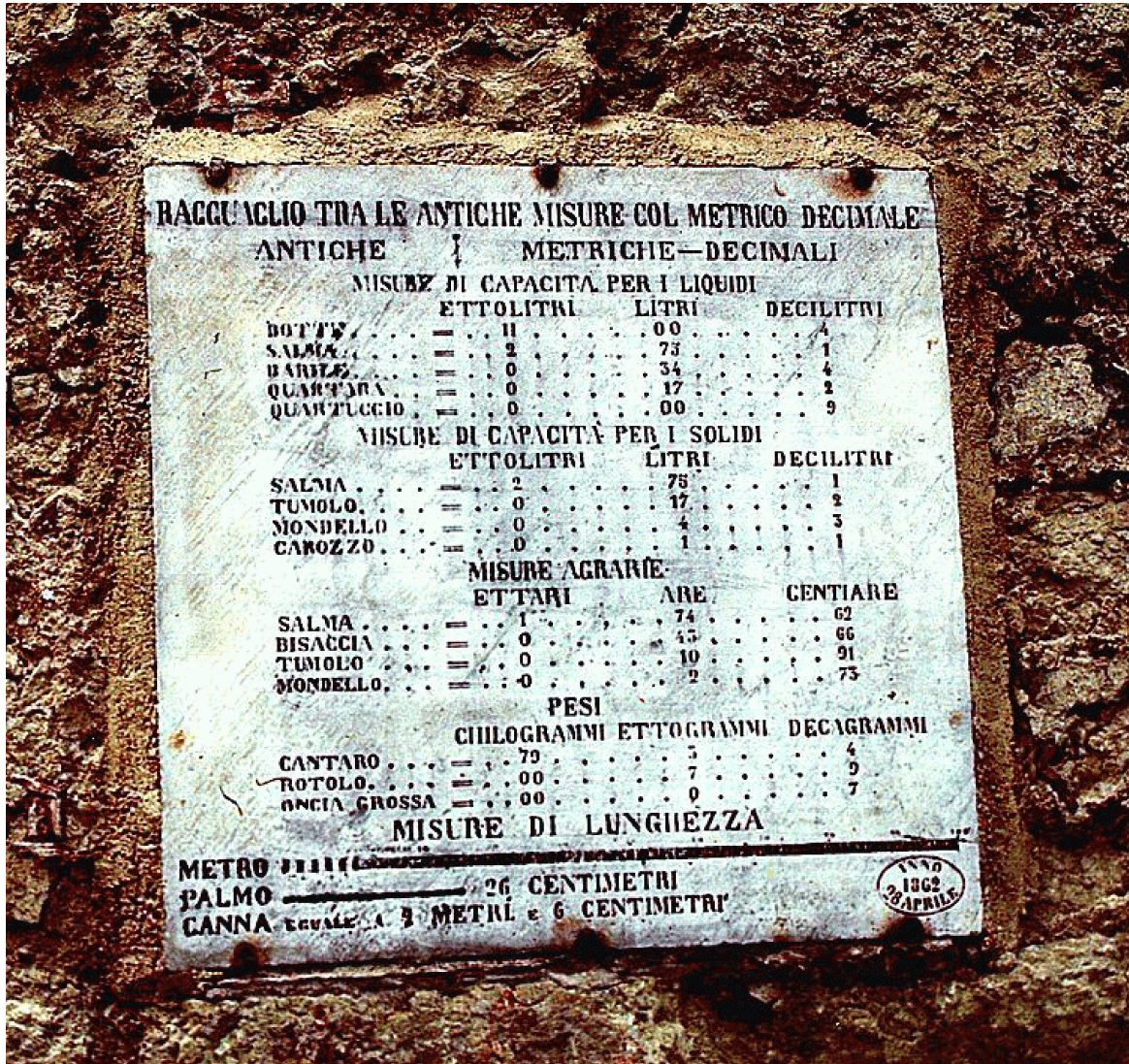


POSITION PAPER ON EU NOISE INDICATORS



27 August 1999

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NOTES

This document reflects the opinions of the majority of the members of the Working Group.

It should not be considered as an official statement of the position of the European Commission.

Not all experts necessarily share all the views expressed in this document.

The European Commission made a financial contribution towards the expenses of the Working Group.

Cover: tableau (1862) from the Church of S. Girolamo, Polizzi Generosa, Sicily. Photo by M. van den Berg.

Executive summary

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Executive Summary (recommendations)

Working Group 1, Indicators, was established on 1st April 1998 by the European Commission to recommend: *physical indicators to describe noise from all outdoor sources for assessment, mapping, planning and control purposes and to propose methods of implementation*. This position paper reports the progress of the Working Group and sets out its first set of recommendations to the Commission for *European Environmental Noise Indicators*.

The Working Group proposes European Environmental Noise Indicators to be used for reporting data on noise exposure outside dwellings. The Working Group recommends that the proposed directive on the Assessment and Reduction of Environmental Noise should require that Member States use the new indicators for *European reporting* for reporting data to the Commission for strategic mapping and planning purposes. In addition, the Working Group recommends that the proposed directive should require that the new indicators for *general applications* are adopted as widely as possible by Member States as soon as it is practicable to do so, given the need to minimise conflict with existing systems of noise measurement and assessment. This is because, in addition to European reporting, there are additional benefits if compatible indicators are used by Member States for other purposes, but this can be left as a matter for negotiation.

The indicators are primarily concerned with the management of reported annoyance and sleep disturbance but may also be useful for the management of other noise-related health effects of environmental noise. The indicators are not intended to indicate sound generated at source, personal noise exposure or noise indoors where different methods may apply.

The Working Group identifies two fields of application for the indicators as follows;

Recommendations for European reporting

The Working Group recommends that the L_{EU} and the $L_{EU,N}$ should be used for reporting data on overall noise exposure for each specific source separately (the specific noise sources would normally be one or more of road, rail, aircraft, or industrial noise or other man-made sources) to the European Commission. The Working Group cautions that the exclusive use of these two indicators may conceal matters of detail which could be important for local assessment (see general applications and additional features below).

The L_{EU} combines the L_{Aeq} 's determined separately for the 12 hour daytime period, 4 hour evening period, and 8 hour night period into one indicator of L_{DEN} format using weightings of 5 dB for the evening period and 10 dB for the night period. The $L_{EU,N}$ is the L_{Aeq} for the 8 hour night period without any weighting.

For harmonisation purposes, it is essential that the length of each period is precisely as defined above, but the start and end times for each of these periods could be defined by each Member State in the light of local circumstances. Accordingly, the Working Group recommends that the Commission should require Member States to adopt the standard default start and end times of 0700-1900 hrs local time (daytime), 1900-2300 hrs local time

(evening) and 2300-0700 hrs local time (night) or to notify the Commission of any differences in start and end times adopted to meet local circumstances. Where any Member State chooses to adopt different start and end times, it is essential that the same start and end times should apply to all noise sources in that Member State.

For harmonisation purposes, the L_{EU} and $L_{EU,N}$ should be determined for incident sound levels at a standard height of 4 metres above the ground: in any calculations or measurements the effects of reflections from the dwelling facade should be excluded; the effects of reflections from the ground directly underneath the measurement point should be minimised as far as possible; and the effects of ground conditions and screens along the propagation path should be included.

Where dwellings are exposed to different specific noise sources on the same or different facades, and wherever it is necessary to aggregate the values of the indicators in some way to derive an indicator of the total noise, then the method of aggregation should be stated. The Working Group makes no recommendations as to how this should be done and cautions that the total will not always give a proper representation of the likely effects considered in aggregate.

The L_{EU} and $L_{EU,N}$ should be representative of the calendar year adopted for assessment.

Numbers of people exposed

The Working Group recommends that the indicators for *European reporting* should be used to indicate the numbers of people exposed to different levels of environmental noise outside their homes. For this purpose, noise levels should be representative of the most noise exposed facades of each dwelling (taking into account the requirement for incident as opposed to facade type sound levels and excluding facades with no noise sensitive parts) so that the numbers of dwellings exposed at different noise levels can be calculated. The Working Group cautions that residential occupancy and census data may not give a proper indication of the amount of time residents spend at home.

Protection of other receivers

The Working Group cautions that steps taken to reduce noise outside dwellings should not proceed without taking into account the need to reduce noise outside schools, hospitals, and similar facilities and to preserve or promote quiet areas. The Working Group recommends that noise outside facilities should be indicated by calculating the noise indicators at the most noise exposed facades of those facilities in the same way as recommended for dwellings.

Key recommendations
for *European reporting* (to be adopted as soon as possible)

- L_{EU} and $L_{EU,N}$ for each source separately
- long term averages
- incident sound levels at 4m above ground
- use most exposed facade

Key *recommendations* (to be adopted in the future)

- L_{Aeq}
- 12 hour day, 4 hour evening, and 8 hour night
- each source separately
- representative averages
- incident sound levels

Quiet areas should be represented on noise maps or in statistical tables by calculating the noise indicators at points distributed over an evenly spaced grid, the grid spacing being appropriate to the scale of the assessment being carried out. In addition, it may be appropriate to indicate the overall character of quiet areas by using additional sound quality indicators, although the Working Group makes no recommendations on this point.

Recommendations for General applications

For *general applications*, the Working Group recommends that the long term average A-weighted sound pressure level in decibels (L_{Aeq}) should be used, expressed separately for each specific outdoor noise source present (the specific noise sources would normally be one or more of road, rail, aircraft, or industrial noise or other man-made sources), and separately for each 12 hour daytime (=activity) period, 4 hour evening (=relaxation) period and 8 hour night (=sleeptime) period.

For harmonisation purposes, it is essential that the length of each period is precisely as defined above, but the start and end times for each of these periods could be defined by each Member State in the light of local circumstances. Where the start and end times for each of these periods has been defined by Member States, they must be the same as those periods used for determining L_{EU} and $L_{EU,N}$. Accordingly, the Working Group recommends that the Commission should require Member States to adopt the standard default start and end times of 0700-1900 hrs local time (daytime), 1900-2300 hrs local time (evening) and 2300-0700 hrs local time (night) or to notify the Commission of any differences in start and end times adopted to meet local circumstances. Where any Member State chooses to adopt different start and end times, it is essential that the same start and end times should apply to all noise sources in that Member State and the total length of each period is not changed.

For harmonisation purposes, the separate specific source and time period L_{Aeq} 's should be determined for incident sound levels: in any calculations or measurements the effects of reflections from the dwelling facade should be excluded; and the effects of ground conditions and screens along the propagation path should be included. For the precise estimation of noise exposure outside individual dwellings, the separate specific source and time period L_{Aeq} 's should be determined at a height appropriate to the most noise sensitive facade of the dwelling, taking into account the effects of any noise mitigation measures like screens or insulation. Where measurements or calculations of separate specific source and time period L_{Aeq} 's are carried out as part of the calculation of L_{EU} or $L_{EU,N}$, then the standardised height of 4m above the ground must be used, and the effects of reflections from the ground directly underneath the measurement point should be excluded as far as possible.

For *general applications*, where dwellings are exposed to different noise sources on different facades, the separate specific source and time period L_{Aeq} 's and the directions from which they come should be noted.

For *general applications*, the separate specific source and time period L_{Aeq} 's should be representative of the calendar year, and if appropriate, the particular season of the year, adopted for assessment. An additional representation for Sundays is recommended.

It should be noted that in all respects other than the height above the ground, the separate specific source and time period L_{Aeq} 's are essential components of the overall L_{EU} and $L_{EU,N}$ described above. This means that if the proposed directive on the Assessment and Reduction of Environmental Noise requires Member States to use the L_{EU} and $L_{EU,N}$ for *European reporting*, then Member States will first have to determine the separate specific source and time period L_{Aeq} 's as part of the calculation of L_{EU} and $L_{EU,N}$. The Working Group recommends that where the use of L_{Aeq} in this way for *general applications* conflicts with existing systems of outdoor noise indicators, then any such conflict should be avoided by changing over to the new system on a date to be set by the Commission. Where other indicators are in use for other purposes, such as the L_{A90} or L_{A95} to measure background noise for particular purposes, and there is no conflict with the European indicators, then there is not the same justification for any change. In such cases the Working Group would nevertheless encourage Member States to consider the potential benefits of increased harmonisation to be offset against any anticipated costs of change.

Additional features

The Working Group notes that reported annoyance and other effects depend on many acoustic and non-acoustic features additional to physical noise levels alone. This may be important when carrying out any assessment or comparison of noise using the European Environmental Noise Indicators and all such features present should be separately and additionally noted. The Working Group can only provide general guidance on how best to deal with any such additional features at this stage.

There are a number of procedures and adjustments in use in different Member States which may be more or less applicable in different circumstances, but the Working Group cannot make any recommendations for the adoption of any one of these procedures to the exclusion of the others. For harmonisation purposes, it is important that the European Environmental Noise Indicators are reported either without adjustments of any kind, or with the nature and magnitude of any adjustments clearly noted so that they can be taken into account in any comparisons made.

Type of noise source

The type of noise source can influence the response. This will usually be important when comparing one source against another, and the type of source or sources should therefore be separately noted.

Variation over time

Intermittent or infrequent noises can be more or less annoying than steady noises at the same long term average noise level. The Working Group offers guidance that noise sources with operating times within the day, evening, or night time periods of less than 20% of the relevant time period, or of less than 20% of the year, or where there is less than 1 event per hour may require special attention. In this context the operating time is the time from the first to the last operation of the day, evening, or night period and may include periods of quiet in between separately identifiable noise events in the case of rail, aircraft or similar sources. Where there is significant variation over time, the nature of this variation should be separately noted. For general applications, where separately identifiable events are more

significant than the overall long term average indicated by L_{Aeq} and L_{Aeq} type measures then additional indicators such as L_{Amax} or L_{AE} (= SEL) may be also relevant.

Tonal or impulsive content

Under certain circumstances tonal or impulsive content can significantly affect reported annoyance, and special efforts should be made to eliminate these features where practicable. Where such features are present, tonal content can be indicated by noting the narrow band frequency spectrum and impulsive content can be indicated by noting the sound level time history. There are a number of different methods already recommended or in use in different Member States which may all be adequate in their own contexts.

Low frequency noise

Subject to the comments made about the additional features described above, the Working Group considers that the A-frequency weighting included within the definition of L_{Aeq} is generally adequate for indicating the physical level of environmental noise under most circumstances, but that where there are high levels of low frequency noise present, then additional indicators may also be required. Measurements or calculations using extended low frequency response as compared to A-weighting will generally be helpful in these circumstances.

The Working Group does not consider that the additional complexity of Loudness Level and Perceived Noisiness Level type measures is justified for European reporting or for general applications.

Implementation

The Working Group regrets that the adoption of its recommendations could entail significantly more changes to existing procedures for some Member States with well-established existing systems of noise indicators than for others. Where there is direct conflict between national and European procedures, the European procedure should eventually take precedence, but on some future date to be set by the Commission allowing adequate time for outstanding administrative matters to be dealt with.

Under those circumstances where any change-over to the new European Environmental Noise Indicator would have a material effect on planning and other regulatory decisions, it is unavoidable that parties may either try to hurry through policy decisions before the change-over date or delay decisions until after the change-over date to their best advantage.

Where there is no conflict, there is no need for any change to existing systems.

The Working Group anticipates that the publication of these recommendations will generate many questions, some of which at least will require further work. The Working Group therefore offers its continued assistance to the Commission in any way in which it might be able to help.

The Working Group would like to thank all its readers for their continued support.

1 Introduction

The EU discussion on environmental noise began with the publication of the Green Paper on Future Noise Policy in November 1996 (this paper was partly based on an inventory prepared by Vallet *et al.*[21]). After receiving comments from many parties from all the Member States, a conference was held in The Hague in May 1997. At The Hague Conference a resolution on the harmonisation of noise metrics was drafted (see box). A second statement concerning environmental noise indicators was made at the EU workshop **A**Road Traffic Noise**@**held in Munich, in 1997. It was stated that **A***The assessment level according to ISO 1996 is suggested for noise measuring. This is to be given separately for daytime and night-time. A harmonized calculation method and noise propagation model should be used for the determination of the assessment level.***@**

At The Hague Conference it was recommended that the conclusions of an international Committee presided over by the Dutch Health Council be taken into account. A summary of the report prepared by this committee has been reproduced in annex 4. In brief, the Dutch Health Council [Gezondheidsraad, 14] recommended the use of two separate noise indicators: the Environmental Exposure Level to assess annoyance during the 24 hour daily cycle and the Environmental Night Exposure Level, for noise associated with sleep disturbance.

Early in 1998 the European Commission formulated Terms of Reference for five Working Groups who are to advise the Commission on European Noise Policy. At the Copenhagen Conference (September 1998) these Terms were discussed and accepted with some amendments. Under the Terms of Reference of Working Group 1, Noise Indicators, the scope of this Working Group has been formulated as follows (see annex 1):

A.1: Noise metric

- !** *The conclusion of the Green Paper that $L_{Aeq,T}$ was to be the basic metric was supported. Though perhaps not **A**perfect**@** it was concluded that no other descriptors are presently available.*
- !** *It was then concluded that two numbers were needed: one to describe annoyance, one to describe sleep disturbance. This leads to various options, for which no preference could be established. Likely candidates are the L_{Aeq} based L_{den} , L_{dn} or variations thereof.*
- !** *It was suggested to await the conclusions of an International Committee chaired by the Dutch National Health Council, which is currently preparing its recommendations on the same topic.*
- !** *In addition to $L_{Aeq,T}$, source specific adjustments would be needed, possibly under the following system:*

| | |
|----------------------------|--------------------------|
| A Physical @ | A Social @ |
| - Tonal | - Road |
| - Impulsive | - Rail |
| - Low frequency | - Air |
| - other? | - etc. |
- !** ***A**Night-time**@**should be the time that people are sleeping. The division between daytime and night-time would need to be a **A**local**@**decision, depending on factors like culture and climate.*
- !** *Future improvements could include a metric for combined exposure to noise from different sources.*

Conclusion of The Hague Conference, May 1997.

This WG will recommend physical and other indicators to be used in the European Union to describe noise from all outdoor sources for assessment, mapping, planning and control purposes (see Terms of Reference for other

WGs) and will propose methods of implementation .

At the same time, the International Standards Organisation started to review the ISO 1996 document [Acoustics - Description and Measurement of Environmental Noise, 16]. Many of the indicators in use these days are based on the standard, but as it dates from 1982, it is in need of updating. Although some progress has been made, a fully reviewed ISO 1996 is not expected until 2003.

Early in 1998, the Commission invited Member States, NGOs, Industry, Local Authorities, the World Health Organisation and the European Environment Agency to contribute to Working Groups to advise the Commission on the technical details of the proposed new framework directive. Working Group 1, Indicators, was established on 1st April 1998 to recommend physical indicators to describe noise from all outdoor sources for assessment, mapping, planning, and control purposes and to propose methods of implementation. The Working Group was requested to select indicators that could be used for the assessment of annoyance, sleep disturbance, complaints, and speech interference in residential situations and also for recreational situations if possible. Where uncertainty exists, the Working Group was requested to make interim recommendations to allow other Working Groups to proceed.

The preliminary findings of the Working Group were presented at a formal conference held in Copenhagen in September 1998. The Working Group then met on several further occasions to finalise its recommendations and the accompanying explanatory Position Paper. The draft Position Paper was presented at the first meeting of the Noise Policy Steering Group held in Brussels in March 1999. Member States and other organisations submitted written comments on the draft over the next few months.

Next, in July 1999, the Commission invited the members of the Working Group to a further meeting to advise the Commission on how best to clarify and revise the Position Paper to take into account all written comments received up to and including 30th June 1999. It was agreed that the chair and co-chair of the Working Group would clarify and revise the text of the Position Paper to reflect the consensus view reached at the July meeting. This document represents the results of that additional work.

This Position Paper represents the consensus view of the Working Group as far as it is understood by the chair and co-chair. As such, it does not necessarily represent the personal opinions of every member of the group. Neither should it be considered as any kind of official statement by the European Commission which is at liberty to adopt or reject whichever recommendations it so chooses. It should be noted that the Commission made financial contributions towards the travel and subsistence expenses of the Working Group, but all members (apart from Mr Tjeert ten Wolde from DGXI) were otherwise completely independent of the Commission.

2 Benefits of harmonisation

There are many different features of environmental noise which contribute to different effects in different situations. Harmonisation of noise indicators wherever practicable is an essential component of European strategy to reduce noise. Harmonisation benefits include:

- direct comparison of noise situations in different Member States;
- facilitating communication on noise problems near borders;
- facilitating the exchange of information between Member States and local authorities, for example on limit values and dose/effect relationships;
- reasonable discussion of international aspects of airport noise and the noise of high speed railway lines;
- monitoring of the noise situation in Europe. This will make it possible to develop a balanced EU noise policy to which local authorities, Member States and the Commission can contribute - especially with regard to noise reduction at source.
- relative costs and benefits of alternative noise control measures can be compared in a consistent manner, something which is almost impossible given the present system of widely disparate noise indicators in use for different noise sources in the various Member States.
- rationalisation of computation and measurement techniques leading to simpler and possibly lower cost instrumentation systems and calculation packages.

(See also [Consultation paper on the limitation of impact of noise from air transport, 32].)

Finally, the new Framework Directive provides a regulatory opportunity for retiring some of the more 'weird and wonderful' historic noise indicators in use in various Member States, which would be unlikely to be adopted as new indicators today.

3 Present situation: differences and similarities

There have been several reviews of the noise regulations in European countries [11,12,21]. From these surveys it is clear, however, that it is difficult to keep up since the regulations tend to evolve. Most authors found it difficult to identify the correct - and more especially - the most current information.

3.1 Road, rail and industrial noise

It appears that in most Member States basically the same noise descriptor is used for road, rail and industrial noise: the long term equivalent noise level, $L_{Aeq,T}$. The only exception is the UK where L_{10} is used for road traffic, while L_{05} is often used for assessing background noise. There are differences, however, in the way the rating sound level is calculated with respect to the input data, the meteorological conditions and the period over which the mean is calculated. **Annex 2** gives an overview.

The effect of these differences may be considerable and they may accumulate. When comparing levels from different origins, these differences can sometimes be accounted for. Ignoring them can introduce differences of up to 5 dB at close range. At greater distances the differences usually increase considerably.

Another major area of difference is the adjustments made for tonal and impulsive noises. The lack of agreement for impulsive noises is most striking: the way of defining impulsiveness as well as the amount of adjustment to be applied differs widely. **Annex 3** gives an overview of current practices.

3.2 Aircraft noise

For calculating air traffic noise the situation is even more confusing. Although in a few cases the ISO recommendation is followed, a number of fundamentally different indicators are in use. Some indicators are based on the maximum level per event (Netherlands), some on other trade-off factors (Germany, Netherlands), and France uses a different frequency weighting (PNL). In addition there is also a wide difference in referencing time periods.

All these differences make it very difficult to compare noise levels between countries or use each others' data from surveys. In recent studies no specific indicators could be demonstrated to have an advantage over others. The general finding is that the indicators correlate well with each other when they are calculated over the same period at one assessment position using the same input data and propagation model.

3.3 Reference time periods

Although it is, to a certain extent, understandable that the start of day and night periods may differ slightly, it is difficult to understand why in one country the noise level at night is calculated over periods - the noisiest - as short as 0.5 hour and in others over 1, 2, 7 or 8 hours.

4 Criteria for selecting noise indicators

When discussing the harmonisation of noise indicators, a set of criteria is required to be able to select from the likely candidates. The criteria for noise indicators depend not only on scientific validity, but also on how that indicator will be used in practice and applied in the legislation. The following set of criteria can be formulated:

- **validity:** relationship with effects.

What effects have to be taken into consideration is largely a political question. In most European countries noise regulations are mainly aimed at the avoidance of considerable annoyance, complaints and disturbance, as well as health effects. A large number of *possible* effects can be derived from the scientific literature. However, a quantitative relationship has been established for just a few of these: i.e. speech interference, annoyance, sleep disturbance (to some extent: for sleep related annoyance a relationship could be established, but the relationship with physical factors, like waking up, is still open to debate), and the risk of an increase in cardiac disease (weak).

- **practical applicability:**

ease of calculation from available data, or measurement using available equipment. Most importantly, it must offer the authorities a reliable basis on which to make decisions about noise reduction measures.

- **transparency:**

easy to explain, intuitive, as simple as possible, relationship with physical units, small number of indicators - preferably one.

- **enforceability:**

use of indicator in assessing changes or when set limits are exceeded. One example is the use of a long term average: if the indicator is based on a year mean, a different approach is needed to demonstrate that a set limit has been exceeded than where an instant maximum level is used which may never be exceeded.

- **consistency:**

as little difference as possible with current practice. In view of the widespread use of indicators, it should be recommended to switch to indicators which belong to a totally different class only if they can be demonstrated to have significant advantages over existing ones.

Although there is general consensus on the criteria, there are differences in the relative importance that should be given to each. Large deviations from these principles may have a major impact on costs. There are two types of costs associated with each indicator: 1) costs related to the introduction phase, which are the one-time conversion costs; and 2) costs related to the practical use of the indicator.

The quest for a single, simple indicator is complicated by the fact that the criteria which are

seen to be the most important are, in part, mutually exclusive. From the point of view of transparency, the simplest indicator would be the non-A-weighted linear sound pressure in Watt. But this would be inconsistent with the criteria consistency and practical applicability, while the validity is still uncertain. Furthermore, the relative importance given to each may differ for different end users.

The first step in selecting an indicator is to draw up sets of possible indicator variants. The variants can then be given a score, after which a ranking can be made. The ranking can be made for different views: if criteria (1) is considered the most important, then a different ranking results than when criteria (2) is considered important.

5 Description of alternatives

5.1 A model for indicators

The Working Group considered the model proposed by Miedema [25] a fruitful basis for their discussions. In this model the design of a noise metric is broken down into discrete, hierarchical steps. The basic concept is that a sound environment can be thought of as being composed of a large number of short sound samples each made up of contributions from different frequency bands. Of course, each soundscape can be recorded in full, but this would produce a huge amount of detail which would not be suitable to base decisions on. The purpose of an indicator is to reduce this large volume of information to a quantity which is still meaningful but easier to handle. It is inevitable that information about individual contributions will be lost, but this has to be accepted. This can be done in much the same way that indicators are made for stock markets and the state of the global climate (based on the average annual temperature).

After reducing the frequency information in the initial step, each subsequent step reduces the time scale by roughly a factor 100. This ultimately results in 1/10 sec noise time-slices. The steps are numbered 1 to 5 in the tree-like figure 6.

The purpose of this breaking down process is to be able to decide which branch to follow based on specific knowledge about the way people react to certain sounds.

1. The first step is to reduce the **frequency** content to 1 number. The A-weighted procedure is most often used. Other possibilities are B, C, D, PNL or Zwicker/Stevens. See Annex 4 for a definition of the procedures.
2. In the second step a value per event is obtained. At present only two procedures are used: either the energetic summation with no weightings, which gives the familiar L_{Ax} or the **maximum level** per event, giving the equally familiar L_{Amax} .
3. The sum of the number of events per day period (day, evening, night). Again there are two commonly known procedures:
 - energetic summation, which gives the \underline{L}_{Aeq} per event
 - summation with a weighting factor of 13.3.As this weighting factor depends on how many less noisy events can be traded for one event at a certain higher noise level, this is commonly known as the **trade-off factor**.
4. In its simplest form without adjustments, the **day, evening and night periods** are summed and averaged to give a 24 hour value. In the more elaborate forms either evening/night or night only corrections are included. Factors of 10 for the night, or a combination of factors of 3.16 (5 dB) for a 4 hour evening and 10 for an 8 hour night are currently in use.
5. In this step the **long term mean** is calculated by means of energetic summation and averaging. Although this is rarely done, this step could further be broken down into weekday/weekend periods, and summer/winter day periods with or without their accompanying weightings.

By breaking down the process, the decision process can be guided by considering at each step what evidence there is for one direction or factor or another. The decisions concerning the best directions or the best factors, will depend on their relationship to the effect to be predicted. It is therefore quite conceivable that different indicators will be needed for

different requirements; an indicator for complaints could look very different from an indicator for sleep disturbance.

Family tree of noise metrics

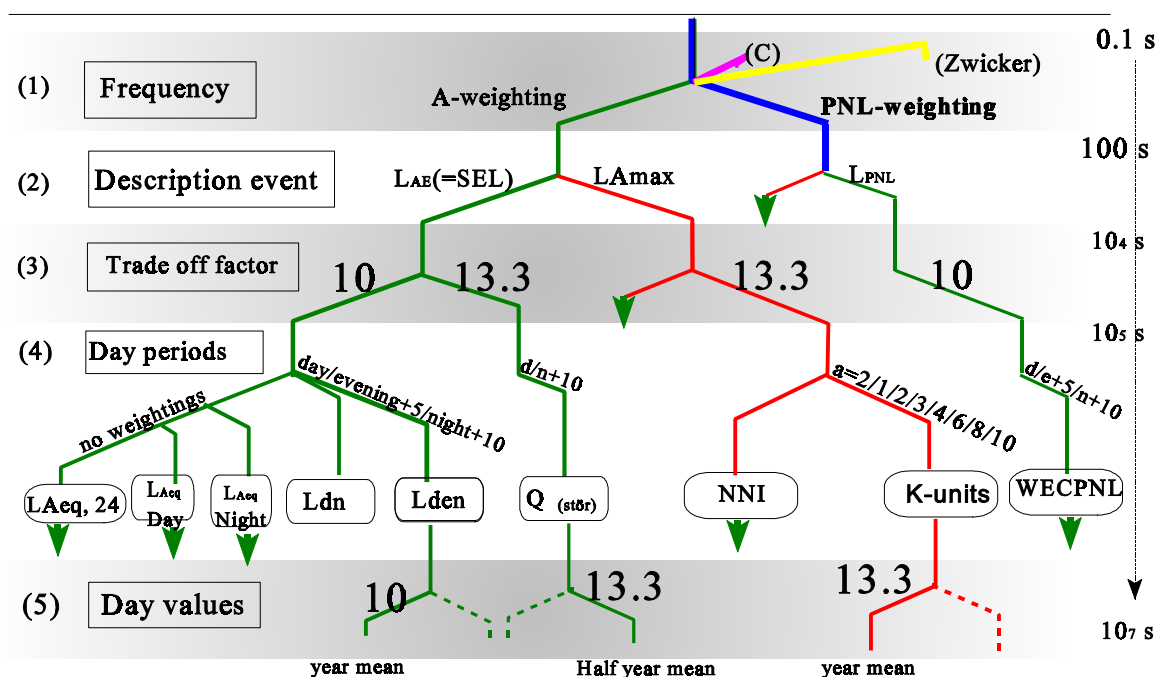


Figure 6 relationships between noise indicators and their structure

It is interesting to see how in this way families of noise indicators begin to emerge. There is an LA_{max} group, with the NNI and the Dutch K-unit. The German Stör-index belongs to the LA_{eq} -group, but shares the trade-off factor of the K-unit. Which is the best, we may ask? Instead of looking at the overall success in predicting adverse effects (a very difficult task with any indicator), it should first be established whether a trade-off factor of 10 is better than one of 13.3. At least this is a simpler question. The same goes for the choice of L_{max} as a basic indicator (layer 2) or LA_{eq} per event.

The figure is very limited. There are literally hundreds of indicators, and if specific local differences were to be included the figure could become very complex.

This exercise can only be done for a limited number of all possible noise effects at present. These are speech interference, annoyance and sleep disturbance. The different aspects are discussed in the following sections.

5.2 Frequency aspects

With the invention of the electrical sound meter it was discovered that the ear has a different sensitivity than the microphone. The greatest sensitivity of the human ear lies around 4000 Hz, and the ear is less sensitive to lower and higher tones. To correct for this, so-called frequency weightings were proposed and readily accepted as early as 1926. In years which followed the A-weighting gained overall acceptance. Without going into much detail (there

is a vast amount of literature on this topic, see Annex 3 and [Kryter, 33]), it can be stated that this simple approach has been under discussion ever since. Although different systems of frequency weighting have been developed (by Stevens and Zwicker, among others), only the Perceived Noise Level (PNL) has had any practical application in some aircraft noise indicators. However, it should be noted that often a simple rule of thumb is used to derive the PNL level from the A-weighted level. In most cases these more complicated approaches have been abandoned by the simpler and more widely accepted practice of A-weighting. Although it can be demonstrated that other frequency weightings have some advantages over A-weightings in predicting **loudness**, there is evidence that applying these weightings does not much improve the correlation between annoyance and indicators based on this.

A special case which deserves attention, however, is low-frequency noise. The A-weighted level tends to underestimate or neglect noise below 100 Hz. (See annex 5 for a precise definition.)

As low-frequency noise has been linked to effects of some severity, and the difference between audible and annoying is very small, special attention must be given to sources where low-frequency noise may be expected or in cases where symptoms (e.g. dizziness, nausea) may give a clue.

A criteria by which to judge whether low-frequency sound could give rise to problems is to look at the difference between the C (or unweighted) sound level and the A-weighted sound level. If the difference exceeds 20 dB, then further analysis for low-frequency is required. Further research may produce more precise information. Another method of measuring and assessing low-frequency noise emissions in the neighbourhood is given by the German standard DIN 45 860.

5.3 Level per event

There are two commonly used methods to evaluate the level of an event. The first is to derive an L_{Aeq} type of indicator, where the total energy content of an event is taken. The resulting value (L_{AE} according to ISO; also indicated as SEL or L_{Ax}) can be used to determine a long term L_{Aeq} . It can also be used as an indicator for short term sleep interference.

The second method takes only the maximum value of an event, thereby ignoring the fact that, given the same L_{Amax} level, an event could be long or short, and presumably a longer event is more likely to cause effects than a very short event. Traditionally, this indicator was easier to measure than L_{Aeq} per passage, and plays a role in older types of composite indicators (Kosten-unit, NNI) and in some regulations. Based on the above considerations, it appears that the first approach gives a more accurate description of the situation, therefore this is the preferred method for use in future indicators.

5.4 Trade-off factor

Basically there are two trade-off factors currently in use: 10, which is equivalent to the physical energy content and 13.3, used in Dutch and German aircraft noise indicators. The effect of a higher trade-off factor is to put more emphasis on the number of events than on their levels. This leads to bigger changes in the indicator when the number of events (airplane passages) change than with indicators based on the equal energy principle. The

following table illustrates this principle for the two trade-off factors now in use; it shows how many events of a certain level are allowed to reach an average level of 50 dB when these events occur in one night of 8 hours.

| Level per event↓ | Number of events that give equal level of indicator | |
|------------------|---|--|
| | trade-off factor 10 (L_{Aeq} 's) | trade-off factor 13.3 (Q, Kosten, NNI) |
| 85 | 10 | 10 |
| 75 | 100 | 56 |

So with a factor of 10 a 10 dB lower level per event may be exchanged for 10 times the number of events (second column), and the same 10 events may be exchanged by approximately 5 times as many 75 dB(A) events in the case of a factor of 13.

Although a considerable amount of research has been done to establish the best fitting trade-off factor [see the discussion in ref. 1 and in ref. 14], this has not produced any clear answer. In field studies, indicators with either higher or lower factors than 10 do not significantly improve the correlation with the effects. It is in view of this that the Working Group recommends that the equal energy principle be applied.

5.5 Definition of $A_{night@}$ and $A_{evening@}$

There are good reasons to suppose that people's sensitivity to outdoor environmental noise varies depending on what they are doing at the time. Many people are away from home at work, at school, or at play for considerable parts of the day and would therefore not be exposed to the prevailing sources of environmental noise in the area at those times. There is some evidence that residents become more sensitive to outdoor environmental noise when they are at home during the evenings, and that they are most sensitive to environmental noise

when they are at home at night. The precise definitions of day, evening, and night vary in different Member States and any attempt at harmonisation here is unlikely to be successful owing to the different weather conditions and cultural norms prevailing at different times of the year in different countries.

However, some general guidelines can be given for the purposes of making an informed decision. Firstly, it is necessary to have access to data about the behaviour of the general

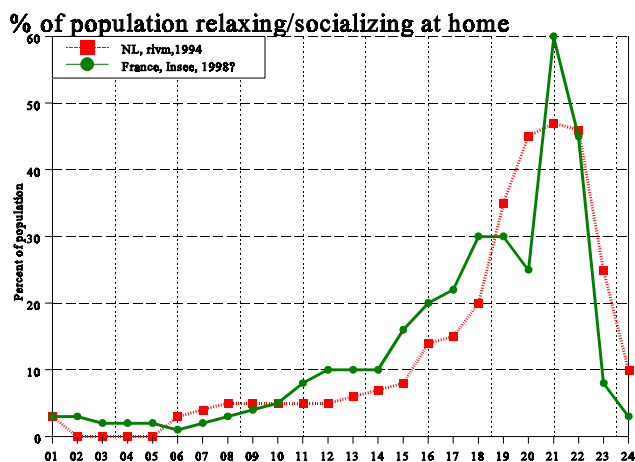


Figure 7 Relaxation at home in the Netherlands and in France

population. Generally, the daytime period will cover the average working day, including any time required for travel to and from work. The evening period will cover the average time set aside for rest and relaxation at home outside of any normal working day (this may include an afternoon siesta period, if required). And, essentially, the night period will cover the average sleeping times from retiring at the end of the day to getting up in the morning. By means of diary research, a very good picture of the behaviour of the general population may be obtained. Examples from the USA and the Netherlands show that this behaviour is remarkably stable over time and over geographic areas.

The figures which follow provide examples of the evening period, expressed as the percentage of people at home and relaxing, and night-time, expressed as a percentage of people asleep.

From figure 7 it can be seen that the beginning of the evening should start somewhere between 16.00 and 19.00 hours, and end between 22.00 and 24.00 hours. Another argument for defining the evening is the sleeping time of young children. From figure 8 it can be seen that the evening is a critical period for children, as it represents the onset of sleeping time. Although children are less sensitive to noise once asleep, most parents will testify that quiet is much appreciated when it comes to putting our little ones to bed!

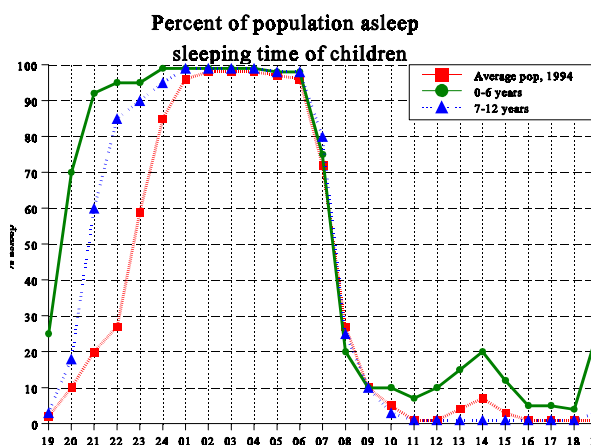


Figure 8 Sleeping time of young children

The beginning and end of the night period can be studied in a similar manner. From the available data ([Fields, 9] and [Freyer, 10]), it is clear that the night period starts and ends one hour later at the weekend. This kind of data can be of great help when comes to making a qualified judgment about evening and night periods.

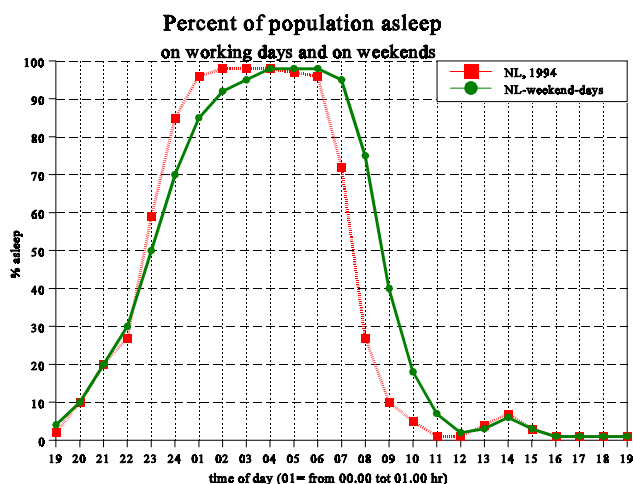
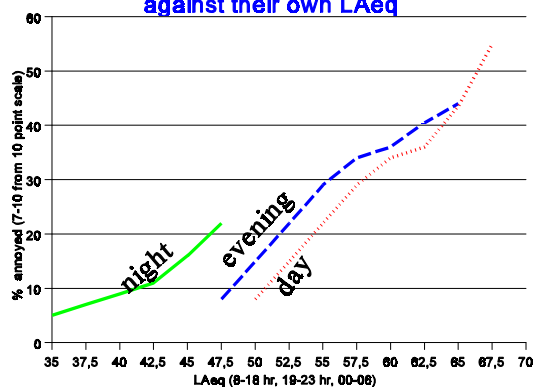


Figure 9 Sleeping times: weekdays and weekends

Something could be said about the length of the night-time. Most people are aware that the mean sleeping time is around 7 ½ hours. Hence the length of the night period cannot be shorter. What is less obvious is that we don't all go to bed at the same time, so the night period needs to be somewhat longer in order to protect the early-to-bed early-to-rise types as well as the late-to-bed late-to-rise types. This leads to a minimum night period of 8 hours. It should be pointed out that in this way around

Day, Evening and Night time Aircraft noise Annoyance against their own LAeq



From: Joint European Aircraft Noise Study, 1986

Figure 10 Annoyance from aircraft noise as a function of the LAeq per period.

time-zone differences which Member States already deal with.

A second recommendation in this area is to keep the weekend, especially Sunday, as a separate identifiable period.

5.6 Evening and night-time weightings

After having defined and assessed the day, evening and night periods the next integration step is to combine these values into one 24 hour level. The simplest way to do this is to combine them without weighting factors into what then becomes a 24 hour average. Obviously, in this way the advantage of calculating them separately for sensitive periods is lost. So if they are to be combined in order to arrive at a single number indicator, a different approach is needed.

As can be seen from Figure 6, most present indicators use at least a night-time correction and some also have an evening correction. If corrections are used, they are 5 dB for the evening and 10 dB for the night (or multiplication factors to this effect, like multiplying the number of events in the evening by 3.16).

It is surprising that there are relatively few studies demonstrating the benefits of these correction factors when it comes to predicting annoyance. It is almost certain that the origin of these factors is derived from the knowledge that night levels are (or were) usually about 10 dB lower than daytime levels, and evening levels were in between. However, this may change in the future and there are well known examples where the difference is already much smaller.

Recent studies [referred to in Gezondheidsraad, 14] showed only slight benefits from various correction factors. The main reason could very well be that there is usually a close correlation between the periods and the differences are small. However, the conclusion was that factors 5 and 10 are not contrary to the evidence, and that better research will probably produce more sound data in favour. Other studies confirm that night-time exposure gives the same annoyance as day time levels that are 10 dB higher. One example of that work is given in figure 10.

50% of the population is protected.

Based on these considerations, the Working Group recommends a 12 hour day period, a 4 hour evening period and an 8 hour night period. The individual Member States will have to define the start and end of the time periods according to local custom and practise. This may cause some slight discrepancies between adjacent countries if they decide on different definitions. However, this is comparable to the present

The Working Group therefore recommends that if day, evening and night levels are combined into one, the 5 and 10 dB correction factors should be used.

5.7 Long term average

Most environmental noise varies from day-to-day, from hour-to-hour, and from minute-to-minute. The variations at the receiving point are caused by:

- a) variations in source strength;
- b) variations in transmission, which are often caused by variations in meteorological conditions.

For most purposes (strategic planning, mapping, zoning, calculation of noise measures), an average over a longer period at the assessment point is needed. It is anticipated that this number will show better correspondence with long term effects. However, for some specific purposes like complaints or other momentary effects an indicator with a shorter time period may be more suitable.

For relatively constant noise or noises with fixed patterns, such as that caused by road traffic, rail traffic, airports or large industrial noise sources, it makes no practical difference whether the basic L_{EU} is determined over a shorter or longer averaging time. However, for irregular or intermittent noise, such as that caused by low flying military aircraft, there will often be a frequency of events below which any long time average of the amount of physical noise present becomes less descriptive of the actual situation. These situations fall outside the scope of this type of indicator, and should be left to individual judgment whenever they occur. Based on practical experience, a rough indication would be to treat different sources which operate less than 20% of the time, or where less than 1 event per hour occurs - averaged over the relevant period. This does not mean that these sources do not cause problems, but that it varies according to circumstances.

Another aspect of the long term average is the relationship with instantaneous sound levels. As with most averages, during part of the time the noise level will be over the average, and the amount will be higher if the time base is shorter. So L_{max} levels (averaging time 125 ms) will be much higher than a year mean L_{Aeq} , but also an hour L_{Aeq} will often be higher (and equally as often, lower, of course).

This is an important aspect which has to be taken into account when setting standards or limits. A short term indicator is much easier to enforce, but says very little about the actual situation, while a long term mean is more complicated to enforce but is likely to have better correlation with long term effects.

What has been said about the variations in source strength, can also be said about the variations in propagation conditions. If the aim is to predict a long term mean, this should also cover the long term variations due to changing weather and ground conditions.

This long term average sound level is almost an abstract entity with an asymptotical character: it can be approached as close as you like (or until resources are exhausted), but it cannot be assessed with 100% certainty. In most cases it will not be possible to have valid measurements under all potential weather conditions. This means that to derive the long term average, a certain amount of calculation has to be done. One procedure is to use downwind measurements (which give a stable, reproducible sound level), and correct them for the average weather conditions. Another method would be to collect as many measurements as

possible for all weather conditions and to calculate from long term meteorological statistics what the sound level would have been. This Working Group does not wish to make any recommendations about the best way, since it is the task of Working Group III, measurements and calculation, to define the assessment methods for long term average noise levels. This WG would like to point out, however, that for most assessment procedures, the short range is more important where meteorological parameters have less influence.

5.8 Assessment position

Comparing noise legislation in different countries often results in different figures which in reality do not necessarily reflect different situations. This anomaly may partly be caused by a difference in assessment points. This section will first review current practice and then discuss a proposal for harmonisation.

International standards and outdoor assessment points

The current ISO 1996 gives as a general measurement position:

- in the free field condition, a distance of 3.5 m from reflecting structures or 0.5 m from an open window;
- near buildings the distance becomes 1-2 m from the façade;
- measurement height is generally 1.2-1.5 m, for land use purposes it can be higher.

Other national standards are very similar. The ANSI Standard 12.9 (part 4) in the US states that all sounds will be measured or predicted as if they had been measured by a microphone outdoors over an acoustically absorptive ground (grass) at a height of 1.2 m with no nearby reflecting surfaces (except ground)@

Free field versus façade

When assessments are made for a situation in front of a building, there are various ways that this can be done:

- assessment in a free field, more than 3-4 m from the façade: in this case the measured level will be the incident level;
- assessment within 1-2 m from the façade: due to reflections the level will be approximately (influenced by the form of the facade) 3 dB higher than the real incident level (3 dB-factor);
- assessment before or at an open window: the level will be the incident level;
- measuring microphone mounted on the window or in the façade: the measured level will be 6 dB higher than the incident level.

Several of the above methods are in use for noise regulations in the Member States.

Height

The height of the assessment position has a major influence on the noise level measured. Assessments which are made at a height of 1.2-1.5 m lead to wide variations in level for

low and medium frequencies. Greater assessment heights reduce the influence of ground effects and low barriers, which improves reproducibility. It is therefore preferable to define noise levels at a greater height than the current 1.2-1.5 metres. A practical solution, where there are no other specific demands, is 4 metres above ground level. If circumstances require lower assessment points, special attention has to be paid to interference effects.

Street side versus rear

For busy street situations the difference in L_{Aeq} between the front and the rear of a building varies depending on the layout of the building and reflections but may reach 15-20 dB. This leads to great difficulties when, for example, noise limits based on traffic density on the street side are used to evaluate complaints concerning rooms at the rear of the building. Research shows that annoyance also depends on the difference between front and back. Current practice is to locate the assessment position on the facade with the greatest exposure.

Outdoor versus indoor

So far, only outdoor emission points have been taken into consideration. The document prepared for the WHO [1] states that it may not be possible to link a specific health effect due to noise with a specific noise source but rather that it is associated with exposure in a specific environment. Therefore interference with communication, annoyance and sleep disturbance are the critical effects in residential situations (these are also the effects referred to in the Working Group's Terms of Reference). These relate for the most part to indoor situations. Sleep disturbance effects refer entirely to indoors (bedrooms). Research shows, however, that these effects are related to inside levels as well as outside levels and - to some extent - the amount of insulation. This is probably due to the fact that, even in northern countries, a large proportion of the population likes to sleep with the windows open (up to 70% of the population), and exposure occurs outside (in gardens, on balconies) which are also sensitive settings.

In terms of international standardisation, indoor measuring conditions are set up in such a way as to avoid amplification in the lower frequencies by keeping the measuring position far enough from windows, walls and floor (1-1.5 m). However, when sleeping, a person's head is usually positioned on a pillow which is less than 50 cm from a wall. This can lead to important differences between measured levels to control prescribed limits and the actual annoyance experienced by the residents.

In view of this the Working Group has not made any recommendations regarding indoor assessment positions. This should be dealt with by the Member States in accordance with their own regulations.

Recommendations regarding harmonisation of assessment position

a. strategic mapping, land use and other planning purposes

The reference point in residential situations is at a height of 4 m, representing the incident level outdoors, including all reflections except reflections from the dwelling itself.

Semi-free field conditions are needed to obtain the incident level which can then be used to make insulation calculations to determine the indoor level, if necessary. If assessments have to be made and free field conditions cannot be obtained in practice, levels should be converted to an incident level condition (for a flat surface this means subtracting 3 dB; but this may differ for oddly shaped surfaces).

b. assessment of abatement measures and control

It is only reasonable to assume that when calculating the insulation of a façade, the noise level outside that façade also has to be calculated, at whatever height it is at. It is equally reasonable to take a height of 1.5 metres when calculating the effect of screens and barriers in gardens.

In these situations the Working Group's recommendation is to assess the incident level at the point where it is most relevant.

6 Possible indicators

There is a wide range of indicators to choose from, some have already been in use for a long time, and some invented only recently. All indicators can be seen as belonging to the Indicator family and the best choice for each step can essentially be decided on the basis of scientific evidence. In practice, however, not all the evidence is available to be able to decide at each step, or the evidence is not conclusive enough to be able to decide whether to turn left or right at a branch. Other criteria also play a role in these decisions. A good example is the frequency weighting step: the better correlations with loudness and more sophisticated procedures would indicate the use of a different weighting than the A-weighting. However, a decision to use A-weighting can be defended on the basis of the practicality and consistency criteria. To narrow the search for indicators, a step-by-step approach is added to the overall model. In the first step a set of basic indicators is selected which is then used to make further selections in the second step (composite indicators) and the third step (complex indicators).

1. basic indicators

basic indicators contain only a few assumptions about the link with effects and can be considered to be purely physical quantities.

2. composite indicators

composite indicators are derived from the basic by combining them in one or more ways: day/evening /night weightings, averages over longer periods.

3. complex indicators

complex indicators cover things such as combined exposure with other noise sources or even other sources of annoyance, and/or take into account the impact on the population.

6.1 Basic indicators

The following table shows possible basic indicators and their overall evaluation with respect to the above criteria.

| Indicators for noise: the basics | Evaluation |
|----------------------------------|---|
| $L_{Aeq,T}$ | Basic ISO indicator. |
| $L_{AE}(\text{A SEL}@)$ | Single event descriptor; weak link with long term effects. |
| rise time (dB/sec) | Only link with startle effects in particular circumstances. |
| L_{Amax} | Single event descriptor; weak link with long term effects. |
| $L_{A(\text{other trade off})}$ | Advantage of trade-offs other than 10 - equal energy - cannot be demonstrated. |
| $L_{Zwicker}$ | Complicated to introduce in practice; advantage over A-weighting not always clear. |
| $L_{Unweighted}$ | Useful when low frequency noise occurs or is suspected. Standardisation required. |
| L_{PNL} | Perceived Noise Level has been abandoned except in Japan, because of complicated procedures whose advantages are not always clear. |
| E_A (N/m ²) | Non-logarithmic Exposure index[4]. Easier to calculate for general public; outcome is counter-intuitive due to the non-linear nature of human reaction. |

Evaluation

In this first step the validity criterion is less important as only links with instantaneous effects can be established. The important criteria here are: practicality, consistency, and transparency.

Although it is claimed that the last indicator (exposure level) is more readily understood by the public, there are some doubts whether this is true in the long run, and if that understanding is really better. An example to illustrate this: an increase in an insulation value from 1000 to 1229 might seem substantial to a lay person, while in fact the difference is completely unnoticeable.

The **Zwicker and PNL frequency** weightings score better in terms of validity (the prediction of loudness is clearly superior), but less well for practicality, transparency and consistency. Although loudness measuring instruments exist, they are certainly not widely used. Most currently available sound measuring equipment is unable to measure Zwicker indexes directly, and the conversion from third octaves is cumbersome. Modern electronics could resolve this problem, but this would mean that most instruments presently in use would have to be drastically altered or replaced. Furthermore, as there is no simple

conversion from A-weighted to critical band, much of the collected research material would become obsolete. The Working Group estimates that at present the disadvantages by far outweigh the advantages.

Indicators with other **trade-off factors** do not seem to score any better for validity (at least in field experiments), and negative for practicality and consistency. Perhaps slightly better on transparency.

Based on validity it is hard to choose between single event metrics L_{AE} and L_{Amax} . Often they are closely correlated when looking at one source at a time. L_{Amax} is often used when assessing complaints and other instantaneous situations, and so scores high in terms of practicality and consistency.

Rise time could be used as a partial indicator for startle effects. Evidence on this is rather scarce (see observations in [1] and [14]).

Conclusion

On the basis of the criteria $L_{Aeq,T}$ is the preferred basic metric:

- A-weighted: practicality. Validity of other frequency weightings is not convincingly better for abnormal situations;
- trade-off factor of 10: validity, transparency and practicality;
- long term average: validity and practicality.

In order to improve validity and transparency it makes sense to distinguish day, evening and night as sensitive periods.

In the next section, therefore, only L_{Aeq} based metrics will be used in composite indicators. Additionally, L_{Amax} could continue to be used for assessing short term noise problems. For the time being, the main shortcoming of the A-weighting - the failure to take low-frequency noise sufficiently into account - can be addressed by using the linear or C-weighted level in addition to the A-weighted level.

6.2 Composite indicators

The general disadvantage of basic indicators is that the link with long term effects is generally weak, or cannot be established at all (as with the single event descriptors). Composite indicators are intended to produce an assessment for a noise situation which occurs over a longer period, e.g. months or years. In order to do this, events have to be added up over a long period of time, as described in section 5.6.

The table below gives possible composite indicators and their overall evaluation with respect to the above criteria.

| Indicators for noise: composite indicators | Evaluation |
|---|--|
| $L_{A(night)}$ | Expected to give a usable approximation of night- time disturbance due to transport noises. |
| $L_{Aday(night+10)}$ | The Aclassic@Ldn (or DNL) definition. Large reliable database of links with annoyance due to transport noises. |
| $L_{Ad(n+15)}$ | Proof for using other night corrections is not convincing. |
| $L_{Ad(e+5)(n+10)}$ | Gives virtually the same relationships with annoyance as <i>Ldn</i> , but gives better protection for sensitive evening period. |
| $\overline{L_{Amax}}$ | An average L_{Amax} over a longer period is probably not much use in predicting effects. |
| L_{10} | This is the road traffic indicator used in the UK. Percentile values are difficult to determine and sometimes give misleading results. |
| L_{50} | Only occasionally used. |
| L_{95} | Often used percentile value to determine background noise. Influence of background noise on annoyance or other effects unclear. |
| EEL | Environmental Exposure Level as proposed by Dutch Health Council. Same level of sound from different sources intends to give the same annoyance effect. Dose-effect relationships for industrial noise are weak. |
| $ENEL$ | Environmental Night Exposure Level. Same level of sound from different sources intends to give the same sleep disturbance effect. |

Evaluation

Validity now relates to long term effects. As already indicated, there is a substantial body of evidence to establish at least the basic dose-effect relationships for annoyance and for sleep disturbance. There is a large volume of annoyance data which has been analysed to give

relationships with L_{dn} and L_{den} . In the *EEL* this information is used to give a single number for all transport noise sources. The relationships for the percentile values have not been extensively studied and because of the inherent shortcomings of this type of metric, it is not expected to give better results. For example, the L_{95} for a railway will generally be equal to the background. The percentile values also score poorly in terms of practicality, because the values are more difficult to establish reliably. It is therefore not recommended to use percentile values as a basic indicator.

From the validity viewpoint, there is not much difference between using evening and night-time corrections of 5 and 10 dB, no corrections at all or only night-time corrections. The reason is probably that in practice these values are closely correlated, so it is difficult to provide evidence for a preference for one over another. From the public's perspective, it would appear to be odd to drop the correction factors, once it has been established that evening and night are sensitive periods. But as there is no compelling reason to deviate from current practice, the continued use of 5 dB for evening and 10 dB for night is recommended.

Conclusion

In terms of all the criteria L_{den} would be a good choice for assessing noise impact due to sources which operate more or less continuously over long periods of time. To assess the impact of night-time noise, $L_{Aeq,night}$ is the indicator of choice.

In line with the results of the basic indicators, it is expected that when assessing situations where low-frequency noise may be present, additional spectral information may be required.

6.3 Complex indicators

Composite indicators can be used for mapping purposes and impact assessment. When it is necessary to compare situations with several noise sources, a complex indicator which takes into account parameters other than acoustical ones may be useful.

A widely used indicator is the amount of population exposed. This can be calculated by counting the number of dwellings exposed to a certain noise level and multiplying that by the average number of inhabitants per dwelling. Often these data are grouped in classes of 5 dB to give a comprehensive overview. When comparing two situations (e.g. before and after the construction of a bypass), it may be difficult to assess the best situation from the raw data. One way to improve this is to calculate the number of people annoyed by multiplying the number of people exposed by the estimated number of people seriously annoyed in their exposure class, as in the next example.

| Noise class | ABefore@ situation | | AAfter@ situation | |
|-----------------|-----------------------|-------------------|----------------------|-------------------|
| | Number exposed | Number annoyed | Number exposed | Number annoyed |
| 45-50 dB | 67000 | 670 | 66000 | 660 |
| 51-55 dB | 12000 | 480 | 14000 | 560 |
| 56-60 dB | 10000 | 800 | 12000 | 960 |
| 61-65 dB | 8000 | 1280 | 7600 | 1216 |
| 66-70 dB | 2000 | 440 | 200 | 44 |
| 71-75 dB | 1000 | 600 | 200 | 60 |
| Total | 100000 | 4270 | 100000 | 3500 |

In this hypothetical town of 100,000 inhabitants an action plan to reduce noise (due to a bypass, for example) is being carried out. From the raw data (number of exposed per noise class) it still may not be clear if the situation has improved. By calculating the number of people annoyed, it can be demonstrated that this is indeed the case (before 4270 highly annoyed persons; after 3500). The factors are derived from annoyance curves, which have become available in recent years.

| Indicators for noise: complex indicators | Evaluation |
|--|--|
| EEL for multiple sources | Although still experimental, it is possible to give an overall evaluation of an area where many sources are present. |
| Number over xx dB | Link with effects is unclear. |
| Area over xx dB | Instrumental when exploring quiet areas. |
| Conflict maps | Results depend on limit values used. |
| Population exposure indicator | Number of people annoyed can be used to assess efficacy of noise abatement measures. |

Conclusion

For certain purposes, such as national or international comparison or other large scale

projects, a complex indicator can be used to produce a one-item map or table. Especially when situations are being compared, the number of maps with basic or complex indicators per noise source becomes so great, that it becomes almost impossible to rank cities or alternative solutions for highways, airports and railways, etc.

7 Range of application

7.1 Indicator uses

In its Terms of Reference, Working Group 1 was asked to define indicators for use in residential situations and, *if possible*, recreational situations. Residential situations are easy to define: in principle, this is the human living environment. Recreational situations can be more complex, and might even be understood to be a noise-generating activity like motor racing.

The Working Group has limited recreational situations to quiet leisure activities in the open air, like walking, cycling or canoeing. Usually, this will be important in nature reserves which admit visitors and in town parks, rural areas or even small villages. Thus, as this concerns mainly the same effects as in residential situations (annoyance, speech disturbance), the same indicators can be used as for the residential situations.

The three types of indicators (basic, composite and complex) can be used for different purposes, depending on the aggregation level in space and time.

The following list gives some examples of these purposes.

Basic indicators:

- useful when dealing with complaints and unusual situations.

Composite indicators:

- useful for overall policy to reduce the number of affected persons;
- applicable in land use planning, mapping zoning and related activities related to noise control;
- to simplify estimation of dose/response effects;
- to simplify mapping;
- can more easily be understood by the public, politicians and planners, etc.

Complex indicators:

- for comparison between countries, regions, cities or parts of a city;
- for comparison of different kinds of sources.
- ultimately, it will make it easier to estimate levels in situations where two or more different sources occur simultaneously.

7.2 Noise sources

The Working Group's Terms of Reference requested indicators for *all outdoor sources*.

Generally, the indicators can be used for all transport noises (road, rail, air, shipping) and most industrial noises. There are no indications that certain types of outdoor sources should be excluded beforehand, apart from the limitations already mentioned. Sources that might come under these limitations could include emergency services' vehicles. Neighbour noise is most definitely not included.

However, special attention has to be given to noise sources with a distinct tonal or impulsive content (see below).

7.3 Impulse noise

It is not possible to lay down definite criteria for impulsive sounds, but in a draft amendment to ISO 1996-2 existing noise sources can be assigned to three different categories of impulsive noise@

- ordinary impulsive sound
- highly impulsive sound
- high-energy impulsive sound

Annex 3 gives more information on this topic, but it is stressed that the debate is still in progress and much is still unclear.

To include impulsive noise in noise maps the relevant sources are calculated using the L_{Aeq} indicator and the impulsive noise sources explicitly marked. This may have the advantage that the noise sources are characterised by their special noise emission properties (impulsivity is not state of the art in noise reduction and should be avoided wherever this is practical).

7.4 Tonal noise

Most of what applies to impulse noise also applies to tonal noise. For distinct tonal sounds the contribution to the L_{Aeq} is calculated and explicitly marked on the map. The literature gives details of current practices for dealing with tonal sounds (see [14] for an overview).

7.5 Conclusions

The indicators described in chapter 6 can be applied to most outdoor noise sources and in most residential and some recreational situations. Additional factors have to be taken into account, however, and in this context the Working Group would like to make specific reference to:

- noise with impulsive content or high rise times;
- noise with tonal content;
- situations where the impact of noise on animals is an issue.

This list is not exhaustive.

8 Link with effects

Several comprehensive reviews of the relationship between noise and effects have been published in recent years ([1],[14],[24],[26] and [28]). The general conclusion is that most of the research is in the field of noise annoyance. Miedema and Vos [24] give the results of a large survey of annoyance data covering over 50,000 cases. Threshold values for annoyance depend somewhat on the source (usually much lower for impulse noise) and range from 40-50 dB, L_{dn} . In this survey all noise levels were converted to this noise metric.

For other effects like blood pressure and cardiovascular disease much less data are available and the results are less clear. In [14] threshold levels for these higher order effects are estimated to be 70 dB($L_{Aeq,day}$). Other reviewers take a more cautious approach, calling for more research on this topic.

Although some data have been collected in laboratory studies on the relationship between noise and sleep disturbance, these results seem to deviate from the results of field studies. Perhaps the best effect parameter is here self-reported sleep quality, which correlates well with night-time L_{Aeq} (for a summary, see [1], [14] and [26]). Depending on the effect end point, threshold levels range from 30- 55 dB (SEL, single event, bedroom) or 20-35 dB (L_{Aeq} , 8 hours, bedroom).

Although specific indicators have been developed for speech interference (see [1] for an overview), there is also a close correlation between the likelihood of speech interruption and the L_{Aeq} . This fact has been demonstrated in various surveys carried out among the general public. Figure 12 shows the relationship based on a compilation of several aircraft noise studies.

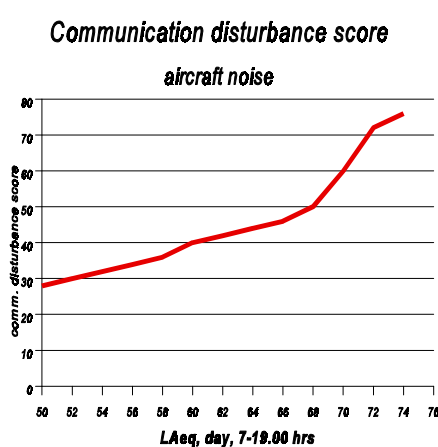


Figure 12 Communication disturbance score for daytime (07.00-19.00 hours) L_{Aeq} from aircraft noise. From: [22], p. 26.

The recommended indicators are primarily concerned with the control or management of annoyance and sleep disturbance and may not be optimum for the management of noise complaints or speech interference, for which other features of the environment may also need to be indicated. Noise complaints can be influenced by many other features than noise level alone, however expressed. Speech interference can be significantly influenced by the time varying frequency distribution of the masking noise in relation to the time varying frequency distribution of the speech, and also by many other features such as information content, native languages, talker and listener effort, etc. Many of these features cannot be adequately represented by any simple physical noise level indicator, however expressed.

However, if there are no changes in any other features, then any reductions or increases in physical noise levels alone would normally result in corresponding reductions or increases

in the number or severity of complaints or in the extent of speech interference. It should be noted that situations where physical noise levels change but there are absolutely no other changes in any other features are unusual. Nevertheless, where such situations occur, then the Working Group considers that the recommended indicators could be of use in these areas as well.

The Working Group briefly considered the application of the recommended indicators to the control or management of other potential environmental noise effects such as changes in long term health, but concluded that there was insufficient evidence to be able to make any recommendations in these areas. However, since most theories of the origin of long term health effects associated with environmental noise involve chronic annoyance and/or sleep disturbance as contributory factors, then the Working Group considered that the recommended indicators could be considered as being generally applicable to other noise related health effects even where there is insufficient evidence to be able to make any definitive statements in this area.

9 Conclusions, recommendations and discussion.

Working Group 1, indicators, was established on 1st April 1998 by the European Commission to recommend *physical indicators to describe noise from all outdoor sources for assessment, mapping, planning, and control purposes and to propose methods of implementation.*

In order to accomplish its task, the Working Group accepted the following considerations with regard to the Terms of Reference:

- *assessment*: the evaluation of noise situations with respect to the effects of noise and ultimately, to avoid excessive exposure.
- *mapping*: creating clear overviews of populations or areas at risk using either geographical or statistical means;
- *planning*: future actions to prevent noise impact;
- *control*: applying policies to improve poor situations or to keep good situations within bounds;
- *implementation*: actions by Member States or local authorities to change their regulations and policies in accordance with EU instructions.

Given the short time available to the Working Group, the scope of the study had to be limited. Therefore indicators referring to sound generated at source have been excluded, as has the indication of personal noise exposure or noise indoors (especially neighbour noise), where different methods may apply.

The Working Group analysed the situation with respect to noise indicators in Europe and found it to be alarming. Under the present conditions no warranty can be given about the comparability of noise levels and therefore of noise policies. The **general finding** is that, indeed, there is an urgent need to harmonise European noise policies. Although it may involve considerable effort for some Member States to implement different noise parameters, the long term benefits could be considerable.

A further conclusion of this analysis is that there are considerable differences between Member States and local governments in the way the noise issue is addressed.

Taking into account the terms of reference as agreed with the Commission; the results of separate consultation exercises carried out within Member States; and the official comments received on the draft Position Paper and Recommendations, the Working Group concluded that there was no need for any substantial changes to the preliminary recommendations made in the draft Position Paper. However, the Working Group felt that the Position Paper would benefit by commenting on the backgrounds of the recommendations to make the Working Group's intentions as clear as possible.

Fields of application

As requested to do so by the European Commission, the Working Group proposes European Environmental Noise Indicators to be used for reporting data on noise exposure outside dwellings. The Working Group recommends that the proposed directive on the Assessment and Reduction of Environmental Noise should require Member States to use the new indicators for **European reporting** for reporting data to the Commission for strategic mapping and planning purposes. In addition, the Working Group recommends that the proposed directive should require that the new indicators for **general applications** are adopted as widely as possible by Member States as soon as it is practicable to do so, given that conflict with existing systems of noise measurement and assessment should be minimised as far as possible. Where there is no conflict, there may be no need to change existing systems for the time being.

Comments

*It became evident to the Working Group that the use of the words 'Strategic mapping and planning purposes' in the draft Position Paper was unclear, particularly when translated from English into other European languages. For the avoidance of doubt, the Working Group decided that two fields of application should be defined **B** European reporting and general applications, for the reasons set out below.*

The Working Group considered that, while there could be many benefits if complete harmonisation of noise indicators was adopted throughout Europe for all noise management purposes, there could be some resistance to this idea, particularly where Member States felt that existing systems were already working well for national purposes. The Working Group did not feel that it could find sufficient arguments in favour of complete harmonisation to be able to recommend this option to the Commission at this time. Therefore, the Working Group concluded that where the continued use of existing noise indicators within Member States does not conflict with the overall aims of the new European policies addressed to the assessment and reduction of environmental noise, then there is no need for complete harmonisation in such areas to be mandatory at this time. For this reason, the Working Group recommends that the new indicators for general applications should be adopted as widely as possible, but that their adoption only needs to be mandatory where conflict with the recommendations for European reporting would otherwise occur.

For European reporting, this is an entirely new application and the Working Group is unaware of any valid objection to complete harmonisation for this application. If comprehensive statistics of national noise exposure using the harmonised indicators are supplied to the Commission on a regular basis, then this will show long term progress (or any lack of progress) towards general noise reduction or to specific noise control action plans.

Recommendations for *European reporting*

For the assessment of overall noise impact, the day, evening and night levels should be combined into one level with a weighting of 5 dB for the evening and 10 dB at night: this is L_{EU} .

$$L_{EU} = 10 \lg \frac{1}{24} \left(12 \cdot 10^{\frac{L_{day}}{10}} + 4 \cdot 10^{\frac{L_{evening} + 5}{10}} + 8 \cdot 10^{\frac{L_{night} + 10}{10}} \right)$$

Additionally the $L_{EU,N}$ is defined as the 8-hour night time L_{Aeq} .

The Working Group recommends that the L_{EU} and the $L_{EU,N}$ should be used for reporting data on overall noise exposure for each specific source separately (the specific noise sources would normally be one or more of road, rail, aircraft, or industrial noise or other man-made sources) to the European Commission. The Working Group cautions that the exclusive use of these two indicators may conceal matters of detail which could be important for local assessment (see *general applications* and *additional features* - below).

Comments:

This recommendation leads to 3 different fields of comment:

- *The choice of the indicator*
- *The use and delimitation of evening and night*
- *The separate use of $L_{EU,N}$*

Choice of the indicator

It should be noted that different indicators of outdoor environmental noise often perform equally well in comparative research. This is because all practical outdoor environmental noise indicators are mostly measuring much the same features of the overall environment. Any differences might only become important in more extreme situations. Most comparative studies have shown that within the normal range of situations found in many urban environments, L_{Aeq} is generally no better and no worse than many existing alternatives in terms of the strengths of association with resulting effects. This means that while changing from one indicator to another could have a significant effect on the outcome of some local assessment it would not necessarily be any more or less valid from the scientific point of view.

This arises at least in part because reported annoyance and other effects can be strongly influenced by many social, economic, and psychological factors additional to the physical noise levels present. For European reporting, it is essential that a single harmonised system of noise indicators be adopted which can support valid comparisons and assessment on a European level. This then has implications for general applications because the indicators for European reporting must be constructed from a wider set of general indicators. It seems inevitable to the Working Group that where there is no other strong reason against, the indicators proposed for general application should gradually take over from generally similar but specifically different existing national indicators for

all those applications where the indicators for general application are appropriate. For local assessments and similar purposes, existing national indicators can remain in place where they do no harm to the overall European policy and they serve a specific purpose which is not met by the new indicators.

day, evening and night

The simplest possible indicator of 24 hour noise exposure would be the 24 hour rms average noise level or 24 hour L_{Aeq} (the use of the A-weighting, etc. is discussed separately below). The Working Group considered that a simple 24 hour average would not give sufficient prominence to the generally smaller number of events arising at night than during the day. In addition, the Working Group felt that the new indicator provided a good opportunity for the evening period to be separately considered in addition to the conventional day and night-time periods. It should be noted that the introduction of a separate evening period does not necessarily imply that the evening period should be treated any differently from the day or night-time periods, but merely that noise events during the evening period or specific noise control actions applying to the evening period will be separately taken into account.

The Working Group decided that the day, evening and night periods should be 12 hours, 4 hours and 8 hours respectively as based on a consensus view reflecting current practice in some Member States. These periods were considered to be generally representative of the typical travel to work, at work, and travel home working day (allowing for some overlap between different individuals); of the typical relaxation and leisure period (note: this can be either in the evening or in the afternoon in different Member States); and the typical night-time sleeping period. For harmonisation purposes, there can be no flexibility regarding the length of these time periods at 12 hours, 4 hours and 8 hours, although the start and end times could be adjusted by Member States to meet local circumstances. The Working Group recommends that the Commission should require Member States to adopt standard default start and end times of 0700-1900 hrs local time (daytime), 1900-2300 hrs local time (evening) and 2300-0700 hrs local time (night) or to notify the Commission of any differences in start and end times adopted to meet local circumstances. Where any Member State chooses to adopt different start and end times, it is essential that the same start and end times should apply to all noise sources in that Member State.

It should be noted that the Working Group makes no recommendations for the start and end times of special restrictions which may be applied to specific noise sources, such as restrictions on the numbers and types of aircraft or other traffic permitted to operate at night. The start and end times of any such restrictions is a completely separate matter from the start and end times for the day, evening and night periods specified for the European indicators, which are merely intended to show the effects of any such restrictions in a properly harmonised way.

The separate day, evening and night period L_{Aeq} 's are combined to give the overall L_{EU} using 5 dB and 10 dB weightings for the evening and night periods respectively, to reflect the increasing importance of noise events occurring during the evening and night periods as during the day. The Working Group did not consider that the available research data

was sufficiently precise to be able to support any particular values of the recommended weightings as opposed to any similar alternatives and this recommendation was therefore based on a consensus view. It should be noted that where the number of noise events per hour falls off during the evening and night-time as compared to during the day (this situation occurs frequently), then without any weighting procedures at all, the effect of evening and night events on the overall 24 hour average is either small or insignificant. With 5 and 10 dB weightings applied, the effect of evening and night events on the overall 24 hour average is much more significant, thus better reflecting the relative importance of these events.

overall night-time noise exposure; the $L_{EU,N}$

As explained above, the Working Group considered that a second overall indicator should be reported to the Commission to represent long term average night-time noise exposure. The Working Group consensus was that this should be simply the 8 hour night-time L_{Aeq} component of the overall 24 hour L_{EU} as described above. In all other respects, the specification for this indicator is the same as for the overall L_{EU} .

One may ask how the L_{EU} and $L_{EU,N}$ relate to each other, as $L_{EU,N}$ is an integral part of L_{EU} . The answer lies in the specific use of the indicators. It is clear that for reporting purposes it is important to have data about an important issue that sleep disturbance clearly is in the mind of the public. If national limit values are set, the question arises if a separate night time protection will be necessary, or that a limit value for L_{EU} will offer enough protection for the night also. It is important to be aware that by consequence of the 10 dB(A) weighting factor, a limit of xx dB(A) for L_{EU} sets a limit of approximately xx-5 dB(A) for $L_{EU,N}$ under the most unfavourable assumptions (no day time noise at all). It will depend on a number of considerations, practical and political, if a choice for a separate $L_{EU,N}$ limit value is made.

The Working Group took into account that sleep disturbance attributable to outdoor environmental noise is more often associated with individual events than with the totality of noise experience throughout the night. This would seem to justify a night-time indicator based on L_{Amax} or SEL. However, this type of event based indicator cannot take account of the number of events which is also important. In addition, individual events vary in magnitude and there is no agreed method for defining a long term average L_{Amax} or SEL. The main advantage of using an L_{Aeq} type indicator in this context is that both the average maximum noise levels of individual events and the numbers of those events are taken into account.

The Working Group cautions that only situations with similar patterns of night time noise events should be compared in this way. It is unlikely that a situation which is otherwise very quiet except for a single very loud noise in the middle of the night will cause the same type of sleep disturbance as a different situation with multiple lower noise level events leading to a completely steady noise climate, even if the L_{Aeq} 's are exactly the same. Where differences in the numbers of events are important, then these should be noted separately as additional features in any reports.

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| The L_{EU} and $L_{EU,N}$ should be representative of the calendar year adopted for assessment. |
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Comments:

The precise method of averaging over time incorporated within L_{Aeq} is interesting. Various alternative indicators give greater or lesser prominence to separate events or to the overall ensemble. Within L_{Aeq} root mean square or so-called 'energy' averaging gives the same numeric value to different time sequences with the same acoustical energy within a given time period and has become a de-facto standard for many applications in recent years. When converted into decibel measures as in L_{Aeq} a doubling or halving of the number of separate events within a fixed time period is numerically equivalent to increasing or decreasing the maximum sound levels (L_{Amax} or SEL) of each separate event by 3 decibels.

*The Working Group concluded that there was no convincing evidence that any other so-called 'trading relationship' between the number and levels of separate events (such as a doubling of the number of events being numerically equivalent to a greater than or less than 3 decibel increase in L_{Amax} or SEL of each separate event) would give any higher correlations with reported annoyance or with sleep disturbance in the general case and therefore recommended that the L_{EU} should be based on L_{Aeq} . The Working Group cautions, however, that where separate noise events are sufficiently infrequent or irregular that the infrequency or irregularity make significant contributions themselves to reported annoyance (or to sleep disturbance) then these features may need to be additionally reported (see additional features **B** below).*

It should be noted that continuous noise measurements over an entire year are unlikely to be required. In many cases, representative data can be obtained by calculation or measurement over much shorter time scales. Where there is significant seasonal variation, for example where noise propagation is significantly affected by meteorological conditions or where there are significant differences in seasonal traffic, it may be appropriate to provide representative data for the different seasons separately for general applications, although for harmonisation purposes, the long term average must still be used for European reporting.

The Working Group also felt that the **weekend**, especially **Sundays**, should be kept as a separate identifiable period and separate values of the noise indicators reported accordingly. However, the Working Group did not feel that this issue was of sufficient priority that it could recommend mandatory reporting of noise levels at weekends to the Commission at this time.

For harmonisation purposes, the L_{EU} and $L_{EU,N}$ should be determined for **incident sound levels** at a standard **height of 4 metres** above the ground: in any calculations or measurements the effects of reflections from the dwelling façade should be excluded; the effects of reflections from the ground directly underneath the measurement point should be minimised as far as possible; and the effects of ground conditions and screens along the propagation path should be included.

Comments:

The Working Group noted a multiplicity of different recommendations for the precise point at which noise levels should be indicated. The many different and largely historical

reasons for this confusion are irrelevant where new indicators are recommended for a new application: *European reporting*. To simplify matters as far as possible, the Working Group recommended that the European indicators should be determined for incident sound levels where the effects of reflections from the dwelling façade should be excluded. In practice, noise measurements are often taken close to a reflecting vertical wall of the dwelling. This is known as a façade measurement. Reflections back to the microphone from the façade add to the direct sound in more or less complicated ways, depending on the different angles and distances involved. This leads to additional complication where measurements are specified in this way. The incident sound level is effectively the sound level to which the dwelling or other noise sensitive facility is exposed when the effects of the structure itself are removed. As such, the incident sound level could be considered as that pre-existing in some place before a dwelling or other facility is constructed at that place.

The Working Group recognises that in densely built up areas, it may be difficult or impossible to avoid reflections from nearby vertical walls. In such cases the Working Group recommends that the person carrying out the assessment should determine the equivalent incident sound level by excluding the effects of reflections in some appropriate way, and that the method used should be stated. It should be noted that for the same sound field environment, incident sound levels will generally be lower than façade sound levels and that any such differences should be taken into account when developing new standards and regulations or when setting targets.

measurement height

The Working Group consensus view was that the standard height above the ground for European reporting should be 4m. This height better reflects noise exposure outside upstairs bedrooms in small two storey housing stock than does the more traditional measurement height of 1.2m above the ground, although it clearly does not represent noise exposure outside ground floor bedrooms or outside bedrooms higher up in multi-storey apartment blocks. In addition, a measurement height of 4m above the ground is less subject to the effects of reflections from the ground close to the microphone than would be measurements at a lower height.

Numbers of people exposed

The Working Group recommends that the indicators for *European reporting* should be used to indicate the numbers of people exposed to different levels of environmental noise outside their homes. For this purpose, noise levels should be representative of the most noise exposed façades of each dwelling (taking into account the requirement for incident as opposed to façade type sound levels and excluding façades with no noise sensitive parts) so that the numbers of dwellings exposed at different noise levels can be calculated.

In practice, human responses may be influenced by additional factors apart from noise level, expressed as one of the recommended *European Environmental Noise Indicators*.

Comments:

The Working Group recommends that the indicators for European reporting should be used to indicate the numbers of people exposed to different levels of environmental noise

outside their homes. For this purpose, noise levels should be representative of the most noise sensitive noise exposed façades of each dwelling (taking into account the requirement for incident as opposed to façade type noise levels) so that the numbers of dwellings exposed at different noise levels can be calculated.

In most residential situations, the most noise sensitive noise exposed façade will be the external wall of the dwelling facing onto and nearest to the specific noise source. However, where the dwelling has been designed with non-noise sensitive rooms such as store rooms on the side facing onto the specific noise source, then it should be permitted to nominate another façade as the most noise sensitive noise exposed façade. The Working Group recommends that the person carrying out the assessment should determine which is the most noise sensitive noise exposed façade, and that where any special considerations have been taken into account, then this should be stated. For the determination of noise exposure statistics on a strategic level for European reporting, the additional complication of selecting alternative façades other than the nearest façade facing onto the specific noise source might not be justified. For general applications, such additional complication may be justified.

It should be noted that this recommendation goes beyond the more traditional type of noise contour mapping which is usually calculated by interpolation from an evenly spaced grid substituted for the actual receiver positions. Calculation at receiver façade positions requires geo-referenced receiver position data in addition to the geo-referenced source position data required for the more traditional type of noise contour mapping.

The Working Group cautions that residential occupancy and census data may not give a proper indication of the amount of time residents spend at home. The amount of time residents spend at home and are consequently exposed to the indicated outdoor environmental noise may be significant when deciding the proper weight to be placed on the results of any calculations.

Protection of other receivers

The Working Group cautions that steps taken to reduce noise outside dwellings should not proceed without taking into account the need to reduce noise outside schools, hospitals, and similar facilities and to preserve or promote quiet areas. The Working Group recommends that noise outside facilities should be indicated by calculating the noise indicators at the most noise exposed façades of those facilities in the same way as recommended for dwellings.

Quiet areas should be represented on noise maps or in statistical tables by calculating the noise indicators at points distributed over an evenly spaced grid, the grid spacing being appropriate to the scale of the assessment being carried out. In addition, it may be appropriate to indicate the overall character of quiet areas by using additional sound quality indicators, although the Working Group makes no recommendations on this point.

Comments:

Little is known about the impact of noise on wildlife, and it seems not very probable that this will improve much in the near future. It can be assumed that policy with regard to quiet areas will focus on recreation close to urban areas. As the same considerations apply here as in the residential areas (annoyance and speech communication being the most important aspects), it is recommended that quiet areas be expressed by the same mapping indicator as is used for residential purposes. On the other hand, in a quiet area a person expects perhaps more than only the absence of speech interference. The use of additional information is therefore not excluded.

Recommendations for general application

For general application, the Working Group recommends that the long term average A-weighted sound pressure level in decibels (L_{Aeq}) should be used, expressed separately for each specific outdoor noise source present (the specific noise sources would normally be one or more of road, rail, aircraft, or industrial noise or other man-made sources), and separately for each 12 hour daytime period, 4 hour evening period and 8 hour night period. In all respects where it is both possible and appropriate to do so, the specification for the indicators for general application exactly matches the specification for the indicators for European reporting and the same explanations apply. The same comments about the A-frequency weighting; 'energy' time averaging in L_{Aeq} and additional features apply.

Comments:

The basic idea behind this is that Member States in the long run will base their national noise legislation on the same elements as where the L_{EU} is based upon. Although it is expected that many Member States will use L_{EU} also for local applications, we see no harm if other choices (=combinations of day/evening/night L_{Aeq} 's with perhaps different weightings) are made based on national views or long standing practice.

Comments

measurement height

For the precise estimation of noise exposure outside individual dwellings, the separate specific source and time period L_{Aeq} 's specified for general applications should be determined at a height appropriate to the most noise sensitive façade of the dwelling, taking into account the effects of any noise mitigation measures like screens or insulation. This is because the standard measurement height of 4m above the ground specified for European reporting will not necessarily be optimum for general applications in all cases. Where measurements or calculations of separate specific source and time period L_{Aeq} 's are carried out as part of the calculation of L_{EU} or $L_{EU,N}$, then the standardised height of 4m above the ground must be used, and the effects of reflections from the ground directly underneath the measurement point should be excluded as far as possible.

multiple noise sources

For general applications, where dwellings are exposed to different noise sources on different façades, the separate specific source and time period L_{Aeq} 's; the directions from which they come; and any additional features of relevance should be noted. Wherever it

is necessary to aggregate the values of the indicators in some way to derive combined indicators of the total noise, then the method of aggregation should be stated. The Working Group makes no recommendations as to how this should be done and cautions that the total will not always give a proper representation of the likely effects considered in aggregate.

year and season of assessment

Where measurements or calculations of separate specific source and time period L_{Aeq} 's are carried out as part of the calculation of L_{EU} or $L_{EU,N}$ for European reporting, then the standard long term averaging period (nominally one year) must be used. However, for general applications, the separate specific source and time period L_{Aeq} 's should be representative of the calendar year, and if appropriate, the particular season of the year, adopted for assessment. This is because the standard long term averaging period specified for European reporting will not necessarily be optimum for general applications in all cases. Where there is significant seasonal variation, for example where noise propagation is significantly affected by meteorological conditions or where there are significant differences in seasonal traffic, it may be appropriate to provide representative data for the different seasons separately for general applications only. Where seasonal data is provided, then the precise conditions to which it applies must be clearly stated.

Additional features

The Working Group notes that reported annoyance and other effects depend on many acoustic and non-acoustic features additional to physical noise levels alone. This may be important when carrying out any assessment or comparison of noise using the European Environmental Noise Indicators and all such features present should be separately and additionally noted. The Working Group can only provide **general guidance** on how best to deal with any such additional features at this stage.

There are a number of procedures and adjustments in use in different Member States which may be more or less applicable in different circumstances, but the Working Group cannot make any recommendations for the adoption of any one of these procedures to the exclusion of the others. For harmonisation purposes, it is important that the European Environmental Noise Indicators are reported either without adjustments of any kind, or with the nature and magnitude of any adjustments clearly noted so that they can be taken into account in any comparisons made.

Type of noise source

The type of noise source can influence the response. This will usually be important when comparing one source against another, and the type of source or sources should therefore be separately noted.

Variation over time

Intermittent or infrequent noises can be more or less annoying than steady noises at the same long term average noise level. The Working Group offers guidance that noise sources with operating times within the day, evening, or night time periods of less than 20% of the

relevant time period, or of less than 20% of the year, or where there is less than 1 event per hour may require special attention. In this context the operating time is the time from the first to the last operation of the day, evening, or night period and may include periods of quiet in between separately identifiable noise events in the case of rail, aircraft or similar sources. Where there is significant variation over time, the nature of this variation should be separately noted. For general applications, where separately identifiable events are more significant than the overall long term average indicated by L_{Aeq} and L_{Aeq} type measures then additional indicators such as L_{Amax} or SEL may be also relevant.

Tonal or impulsive content

Under certain circumstances tonal or impulsive content can significantly affect reported annoyance, and special efforts should be made to eliminate these features where practicable. Where such features are present, tonal content can be indicated by noting the narrow band frequency spectrum and impulsive content can be indicated by noting the sound level time history. There are a number of different methods already recommended or in use in different Member States which may all be adequate in their own contexts.

Frequency aspects of noise

Subject to the comments made about the additional features described above, the Working Group considers that the A-frequency weighting included within the definition of L_{Aeq} is generally adequate for indicating the physical level of environmental noise under most circumstances, but that where there are high levels of low frequency noise present, then additional indicators may also be required. Measurements or calculations using extended low frequency response as compared to A-weighting will generally be helpful in these circumstances.

Comments:

The Working Group does not consider that the additional complexity of Loudness Level and Perceived Noisiness Level type measures is justified for European reporting or for general applications.

Other recommendations

- It is vital that all the information needed for calculating noise levels is supplied unconditionally by those in charge of the source. The Working Group would like to see this explicitly stated in the Directive.
- The Member States need sufficient time to make the transition to the new indicators. A period of four years is probably required.

10 Implementation Methods

Once a common set of indicators has been accepted, it will have to be incorporated in the regulations of the Member States. Particularly in Member States where noise regulations already exist (the majority; only Spain and Greece appear to lack any formal regulations at national level) this may require major changes.

It is necessary that the central authorities in the Member States are aware of the problems that could arise when implementing a new set of noise indicators in their regulations. The regional and local authorities also play an important role here. A common goal can never be achieved without the cooperation of the local authorities, since they are the users and must agree to and actively ensure implementation.

It will take time to switch to new indicators. A country which works with five-year environmental programmes, for example, will not be using the indicators until the next environmental programme takes effect.

A particular problem is that in most cases the numerical value of the common indicator will differ from the local variety. In order to maintain the same level of protection, the values of the standards or limit value have to be changed. Unfortunately, there is no simple rule of thumb which can be applied to these differences because they depend on the source as well as distance.

To implement new noise indicators the following needs to be considered:

- A clear description of their purpose and disadvantages.
- It is estimated that a period of at least four years will be required in situations where extensive regulations are already in force.
- The local authorities in the network of Working Groups and cities need to play a key role in their countries. They represent major cities and deal with overall noise questions in each of the countries.
- The discussion on indicators should be kept separate from any discussion about limits and any major changes in the fundamental work on noise.

11 Recommendations for future work

General

WG-1 or a successor to it will be needed to support the implementation of these recommendations.

WG-2 recommendations:

- There is an urgent need for information on population activities over time (especially sleeping behaviour).
- A better understanding of the influence of quiet periods over the year and seasonal variations could make the prediction of effects more accurate.
- A better understanding is required of the influence of the number events on effects.
- An effort should be made to harmonise impulse noise (definition and penalties).
- There is little data available on the effects of industrial noise; this needs to be rectified.

WG-3 recommendations:

- Calculation methods are needed to derive long term means, preferably simply.

WG-4 recommendations:

- Harmonisation of methods to assess the value of a $A_{\text{soundscape}}$ is needed.

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| WG-1 Indicators |
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1. Scope

This WG will recommend physical and other indicators to be used in the European Union to describe noise from all outdoor sources for assessment, mapping, planning and control purposes (see Terms of Reference for other WGs) and will propose methods of implementation.

2. Objective and work programme

The recommended indicators will mainly be used for the assessment of annoyance, sleep disturbance, complaints and speech interference in residential situations and possibly, recreational situations. The recommendations of the Working Group will take into account the following factors:

- the indicators must take into account current understanding of the relationship between the degree of noise exposure and the resulting effects;
- the indicators should contribute to increased public understanding and therefore should be as simple as possible while avoiding confusion;
- the indicators should properly represent as many of those features as possible of the acoustic environment which are relevant to any assessment being carried out; this includes specification of the point that the indicator refers to, and the start and end of relevant time periods (day/evening/night or workday/weekend, etc.);
- the level of accuracy required;
- where possible, the indicators should avoid conflict with existing indicators already in use by Member States.

Any fundamental knowledge which is required but cannot be made available within the reporting period for the Working Group will be set down as further research needs. Where uncertainty exists, the Working Group will make interim recommendations to allow the work of the other Working Groups to proceed.

Time scale

Start of work: June 1998.

Presentation of preliminary findings: September 1998 (Copenhagen Conference)

Draft position paper: December 1998

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annex 2 Summary of indicators and criteria in use in Member States

2.1 Road, rail, industry

Table 1. Methods of expressing L_{Aeq} per country with respect to meteorological conditions, time-averaging and façade reflection.

| | Road | | | | Industry | | | | Rail | | |
|-----------------|------|----|---|---|----------|----|---|---|------|----|---|
| | LT | DW | N | F | LT | DW | P | F | LT | DW | F |
| Austria | | X | | | | X | | | | X | |
| Belgium Flemish | | | | | X | X | | | | | |
| - Brussels | | | | | | X | | X | | | |
| - Walloon | | | | | | X | | | | | |
| Denmark | | | X | | | X | | | | X | |
| Finland | | | X | | | X | | | | X | |
| France | X | | | X | | | X | X | X | | X |
| Germany | | X | | | X | | | | | X | |
| Greece | | X | X | X | | X | | X | | X | X |
| ISO | X | X | | | X | X | | | X | X | |
| Ireland | | | | | | | | | | | |
| Italy | X | | | X | | | X | X | | | X |
| Luxembourg | | | | | | | | | | | |
| Netherlands | X | | | | X | | | | X | | |
| Portugal | | | | | | | | | | | |
| Spain | | | | | | | | | | | |
| Sweden | | | X | | | X | | | | X | |
| UK | | | | | | | | | | | |

LT = long term mean

DW = down wind conditions

N = neutral conditions

P = prevailing conditions

F = includes building reflection at receiving point

When the noise source has impulsive or tonal components, different methods are in use to take this into account (see annex 3, on impulsive noise).

2.2 Aircraft noise

Table 2 gives an overview of rating sound levels for aircraft noise and the principal elements used in the formulas, like A-weighting vs PNL, L_{Amax} vs L_{AE} , and the weighting factors per passage.

Table 2

Rating methods for aircraft noise

| Country | Lmax | SEL | Trade-off factor | Averaging time | Evening period specified | Night Period |
|-------------|------------|-----|------------------|----------------|--------------------------|--------------|
| ISO | | X | 10 | ? | ? | ? |
| Netherlands | X | | 13.3 | year | 18-23 | 23-06 |
| BRD | | X | 13.3 | 6 months | no | 22-06 |
| France | X (PNL) | | 10 | 24 hour | no | no |
| Austria | | X | 10 | 24 hour | no | 22-06 |
| Scandinavia | X (F or S) | | 10 | 24 hour | no | no |
| WECPNL | EPNL | | 13.3 | 24 hour | yes | yes |

annex 3 **Impulse noise and tonal noise**

It is not possible to lay down definite criteria for impulsive sound, but in a draft amendment to ISO 1996-2 existing noise sources can be assigned to three different categories of Aimpulsive noise@

- ordinary impulsive sound
- highly impulsive sound
- high-energy impulsive sound

as shown in Table 1.

| Category | Sound source |
|-----------------------------|--|
| highly impulsive noise | small arms fire metal hammering wood hammering drop forging metal impact of railyard shunting operation drop hammer pile driver pneumatic hammering pavement breaking |
| high-energy impulsive noise | quarry and mining explosions demolition and industrial processes that are highly explosive explosive industrial circuit breakers military ordinance sonic booms |
| ordinary impulsive noise | outdoor ball games (soccer, basketball) car door slams (bird song) |

Table 1: Impulsive sound sources

The table clearly shows that only a very small number of noise sources can be considered to be impulsive. Surveys have shown that only 20% of people describe the noise from industrial noise sources as having impulsive content. Assessment of these noise sources in order to determine long term noise exposure and including them in noise maps gives the following results:

- traffic noise is not impulsive (very few exceptions);
- outdoor ball games and church bells are not subject to assessment for noise maps;
- drop hammer pile driving, pneumatic hammering, pavement breaking are operations in connection with construction work and construction sites, since these do not normally involve long-term exposure they should not be subject to assessment for noise maps;
- sonic booms are not a problem in Europe, they occur occasionally and the

number of events is not predictable.

Only a few sound sources have an impulsive character and these sources are mainly found in trade and industry. In the context of noise mapping only the following noise sources should be taken into account:

- small arms fire, military ordinance;
- metal hammering, wood hammering, drop forging,
- quarry and mining explosions;
- demolition and industrial processes that are highly explosive;
- explosive industrial circuit breakers;
- metal impact of railyard shunting operations.

Annoyance and rating

Impulsive noise may be more annoying than non-impulsive noise where each of them produces the same equivalent level L_{eq} . Impulsive noise is rated by making adjustments to the relevant L_{eq} of the impulsive noise. Research shows that there is a very wide range of possible adjustments for impulsive noise, from 2 dB up to 15 dB, depending on the circumstances. Regulations in the Member States lay down various adjustments (depending on the tradition in the countries concerned). Table 2 shows the adjustments made for impulsive noise in some Member States.

This table is derived largely from [4] (1995).

| Differences in tonal and impulse corrections for different countries | | |
|--|-----------------------------------|--|
| Country | K_T in dB | K_I in dB |
| Austria | 3 or 6 | 3 if $L_{A,I,max} - L_{A,F,max} < 2$ dB 5 if $L_{A,I,max} - L_{A,F,max} > 2$ dB |
| Belgium; Flemish | 5 or 2 music : 5 | $L_{A,i,max} < 2$ sec difference $L_{A,I,max}$ and L_{Aeq} : <20 dB day, <15 dB evening and night |
| Belgium, Brussels | 2 to 6 | $L_{A,I,eq} - L_{Aeq}$ |
| Belgium, Walloon | 2 to 6 | 5 if $L_{A,I,max} - L_{A,S,max} > 5$ dB |
| Denmark | 5 | 5 |
| France | 5 | 3 or 5 or 10 depending on duration and $L_{A,F,max} - L_{Aeq}$ |
| Germany | 3 or 6 | $L_{A,I,eq} - L_{Aeq}$ or $L_{A,FT,eq} - L_{Aeq}$ |
| UK (only K_T or K_I) | 5 | 5 |
| Italy | 3 | 3 if $L_{A,i,max} - L_{A,F,max} > 6$ dB , and $L_{A,F,max} < 1$ sec, and $N > 10$ in daytime or $N > 2$ in nighttime. |
| Netherlands | 5 (audible tones) | 5 (audible impulses) |

where K_T is the correction in dB(A) for tonal noise and K_I is the correction in dB(A) for impulse noise to be added to the L_{Aeq} of the sound.

Predicting noise exposure or annoyance due to noise exposure caused by noise sources with an impulsive character

For noise maps it is difficult to use the adjustments in the table. They may depend on the height of the impulse, the number of impulses, the distance from the impulsive source, and possible noise reduction measures. The last amendment to ISO 1996-2 proposes that the annoyance caused by impulsive noise should be considered by making a fixed adjustment to the normal energy equivalent level L_{eq} (see Table 3).

| Characteristic of sound | Adjustment |
|-----------------------------|-------------|
| ordinary impulsive sound | 5 |
| highly impulsive sound | 12 |
| high-energy impulsive sound | not defined |

Table 3: Fixed adjustments for impulsive noise according to ISO 1996-2

There are different methods available to predict noise exposure in the neighbourhood of impulsive noise sources:

A.

The equivalent level L_{eq} is calculated based on emission values (sound power levels) of the source and the adjustments corresponding to ISO 1996-2 are added (fixed values depending on the character of the noise source: ordinary, highly or high-energy (?) impulsive). This sum may be used as the rating level and may be presented in a noise map.

The procedure of adding fixed adjustments is not very sensitive and when compared with the high standard of calculating noise exposure this may produce a relatively rough estimate which does not take into account variations in impulsivity depending on distance, background noise exposure from other sources (which may or may not be impulsive) etc.

B.

The equivalent level L_{eq} is calculated based on emission values (sound power levels) of the source and adjustments corresponding to one of the more sophisticated methods in Table 2 are added. This sum may be used as the rating level and may be presented in a noise map.

Difficulties can occur because:

- peak values of impulses cannot be predicted for long-term rating;
- number of impulses cannot be predicted for long-term rating;
- impulsiveness of noise exposure depends on distance from the source;
- several impulsive or non-impulsive sources may cause exposure at the receiving point.

annex 4 Executive summary: Assessing noise exposure for public health purposes@

Executive summary

In this report, the 'Uniform environmental noise exposure metric' Committee of the Health Council of the Netherlands proposes a system of environmental noise exposure metrics for risk assessment of and policy decision-making on the adverse effects of environmental noise on the health and well-being of residential communities.

Request for advice and background

The Minister of Health, Welfare and Sport and the Minister of Housing, Spatial Planning and the Environment requested the Health Council to recommend a system of environmental noise exposure metrics. This system should be simple, transparent, in agreement with binding international regulations, and applicable to all environmental noise sources outside the home. The request is to be viewed against the background of the present use of a variety of source-dependent noise metrics associated in different ways with noise-induced health effects.

The present report, which answers the Ministers' request, is part of the national policy project MIG: Modernising Instrumentarium Geluidbeheer (Modernization of Policy Tools for Noise Management). This project should result in a policy revision that aims at simplifying the environmental noise regulations by introducing more transparency, flexibility and delegation to provincial and municipal authorities.

Specification of adverse effects

The request for advice was limited to exposure to environmental noise. The former Health Council Committee on Noise and Health showed in its report that noise-induced general annoyance and sleep disturbance are the most widespread effects of environmental noise on the population of the Netherlands. The system of noise metrics is developed in such a way as to be able to assess these effects within communities in residential areas independent of the type of noise source. This is done by adjusting physical noise exposure metrics, using exposure-response relationships based on empirical data, in such a way that source-dependent differences in the exposure-response relationships disappear.

In surveys it is common practice to specify the degree of general annoyance in a population by the 'percentage of the population that is highly annoyed' (%HA). A subject is considered to be highly annoyed if he (or she) rates his (or her) degree of general annoyance on a scale from 0 to 100 with a score of 72 or over. ('Not at all annoyed' is at the lower end of the scale and 'extremely annoyed' at the upper end.) This measure of general annoyance is also used in this report.

Sleep disturbance is specified here by two measures of effect, one for sleep disturbance annoyance and another for awakening. Similarly to general annoyance, sleep-disturbance general annoyance is assessed by the percentage of people highly annoyed by noise-induced sleep disturbance (%HS). Awakening is specified, only for situations involving isolated noise events during sleeping time, by a count of the number of noise-induced awakenings in an adult person.

Basic concept of the system

The Committee proposes a system of two metrics to quantify long-term environmental noise exposure in communities:

- a EEL : environmental exposure level, associated with general annoyance due to long-term exposure to environmental noise during the 24-hour daily cycle
- a ENEL: environmental night-time exposure level, associated with sleep disturbance (annoyance and awakenings) due to long-term night-time exposure to environmental noise.

These metrics are specified in such a way that, irrespective of the type of noise source, situations in residential areas with the same EEL lead to approximately the same level of general annoyance in a community. Similarly, in situations with the same ENEL,

communities would experience approximately the same level of noise-induced sleep

disturbance.

The available data are insufficient to complete the full specification of EEL and ENEL. Therefore the Committee starts the uniforming process with the introduction of the noise metrics $L_{adjusted,den}$ and $L_{dj,,,d.23-07h}$. These metrics are explained below. The Committee indicates the actions that should be undertaken to specify the system completely.

Determination of EEL

The determination of the EEL for a specific environmental noise source starts by expressing exposure to noise from that source during a part of the day by means of the equivalent sound level during that period. Then differences in general annoyance which depend on special characteristics of the noise (e.g. tonal and impulsive components, the period of the 24-hour daily cycle in which the noise occurs and the type of noise source) are taken into account.

In the first step for determining the EEL, adjustments are applied to the equivalent

sound level to account for special noise characteristics. These adjustments are appropriate in the following situations:

non-impulsive continuous industrial noise: adjustments are tentatively proposed for application which vary from 0 to 10 dB(A)

situations with audible tones in the noise: adjustments are tentatively proposed for application which vary from 0 to 5 dB(A)

situations with (highly) impulsive components: adjustments are 5 or 12 dB(A).

Adjustments for tones and impulses are generally not deemed necessary for situations involving common modes of present-day transport. The Committee recommends that the need for adjustments for tonal or impulsive components be the subject of a study for new modes of transport.

In the next step, the three (adjusted) equivalent sound levels over the three periods of the 24-hour daily cycle (day-time: 07.00 - 19.00 hours ; evening-time: 19.00 - 23.00 hours; night-time: 23.00 - 07.00 hours) are determined and adjusted with respect to the time of occurrence of the noise,, by adding 5 dB(A) to the adjusted equivalent sound level during the evening and 10 dB(A) to the adjusted equivalent sound level during the night. In addition to this, an exponential average of the three adjusted equivalent sound levels is calculated to determine a value representative for the full 24-hour period ($L_{dj,,,dd,,}$).

The final step in the derivation of EEL, the uniform environmental noise exposure metric related to general annoyance, would be to adjust the adjusted equivalent sound level for the 24-hour daily cycle in such a way that the exposure-response relationships for aircraft and rail (train and tram) traffic noise coincide with those for road traffic noise and stationary noise sources, such as industries, shooting ranges and shunting yards. However, the Committee stops short of making this final step, the main reason being that agreement must be reached on the most appropriate measure of effect. Although %HA is widely used, other measures are prescribed in some regulations. As the decision on this matter is largely of a political nature, the Committee presents its derivation of the EEL as an example.

Determination of ENEL

To determine the ENEL, the noise exposure from 23.00 to 07.00 hours is considered. As specified for the determination of the EEL, the equivalent sound level is adjusted to account for special noise characteristics to obtain $L_{adjusted,d.23-07h}$. Then adjustments that take into account the type of noise source should be applied. The Committee is not able to make this final step, since the exposure-response relationships for the various noise sources require further evaluation before they can be taken as sufficiently stable for specifying ENEL. The report presents preliminary exposure-response relationships for sleep-disturbance annoyance for situations involving transport noise and noise from stationary sources, and a preliminary relationship for the maximal number of noise-induced awakenings in adult persons which is limited to situations with isolated noise events during sleeping time. From these relationships an indication of the adjustments required is obtained.

Discussion of the proposed system

The Committee is of the opinion that, to a large extent at least, the system meets the requirements put forward in the request for advice.

- Transparency

The system has a high degree of transparency. Using the two proposed metrics EELand ENEL, in many relevant situations of environmental noise exposure the expected general annoyance and sleep disturbance can be estimated from simple relationships, irrespective of the noise source. Also, the system with and Ladjusted.23-07h is much more transparent than the present Dutch system.

- International agreements

The proposed system is to a large extent in accordance with the authoritative ISO document 1996-2 on the description and measurement of environmental noise pertinent to land use. The system is also in line with the conclusions of the international conference on future EU noise policy, held in May 1997 in the Netherlands (The Hague).

- Simplicity of assessment and measurement

The proposed noise metrics are based on the equivalent sound levels during specific parts of the 24-hour daily cycle. These equivalent sound levels can in principle be easily used in noise emission and immission calculation models and measured with simple, relatively inexpensive acoustical equipment. The Committee recognizes that measuring environmental noise in practical situations is complicated due to e.g. (noise from) intervening human activities, variations in noise situations from day to day and requirements for noise-source specific measurement results. In most instances, the determination of special characteristics of noise requires advanced acoustical instrumentation. However, a proper assessment of these special characteristics, which is relevant in only a minority of cases, is necessary and unavoidable to prevent underestimation of the levels of general annoyance and sleep disturbance.

The noise metrics have been specified as values representative for a year. It is common practice to determine noise exposure for national, regional or local purposes either by using calculation methods or by extrapolating the results of (representative) samples of measurement results. In both instances this requires specific expertise which is sometimes beyond the knowledge of the users of the system. However, any other system of metrics for the reliable estimation of noise-induced adverse effects would also require such expertise.

-Applicability

It is expected that the system will be applicable to the large majority of situations involving environmental noise exposures, such as situations with exposure to noise from road, rail and aircraft traffic and from industries, shunting yards and shooting ranges. It is important to note that the system of metrics is designed to assess health effects due to long term environmental noise exposure, and not to assess health effects shortly after the noise levels show a sudden change, e.g. due to noise reduction measures in the neighbourhood or the use of a new railway line.

Exposure to infrequently occurring noise from, for example, the occasional passage of a helicopter (for rescue purposes), ultra-light aircraft and small aircraft (for advertising purposes), or pop concerts and sporting events cannot be assessed using the proposed metrics. The Committee recommends further research on this subject.

The Committee recognizes that noise from neighbouring dwellings and from activities in the near vicinity is an important cause of general annoyance. However, nonacoustical factors play a role in people's appraisal of such noises to a larger extent than in the case of traffic noise. Therefore it is considered unlikely that the proposed system, even with amendments, will be able to predict general annoyance in these situations. Further psycho-acoustical surveys may be able to reveal important acoustical, psychological and social variables in this respect.

It has been found that people's reactions to low-frequency noise, once they perceive this type of noise in their living environment, are usually so severe as to suggest that appropriate adjustments may be in the order of 40 dB(A). The Committee recommends further investigation on this subject before applying the proposed system of metrics (with incorporation of the appropriate adjustments) in such situations.

The Committee is of the opinion that inclusion of a detailed recommendation for rating high-energy impulsive noises such as sonic booms, was beyond the scope of the present report.

The Committee discussed the possibility of using the proposed system of metrics for assessing the combined effect of two or more different noise sources, each producing similar general annoyance or sleep disturbance. As yet, there is no generally accepted method to assess this effect. Also taking into account the limited available time, the committee considered it not possible to formulate a proposal for this complicated subject at this moment.

annex 5 Glossary of terms used in noise control

Noise

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

Sound

Sound is 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. Since annoyance can mean different things to different people at different times, it is not meaningful to define annoyance any more precisely. Reported annoyance is normally understood to mean 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 understood. 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

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/m^2). 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.

Root mean square average

The simple average sound pressure over time is close to zero irrespective of the amplitude of the sound wave because the positive and negative excursions of instantaneous pressure above and below the static atmospheric pressure tend to cancel out. Therefore, the simple average sound pressure would be useless as an indicator of environmental noise.

The root mean square average does not suffer from this disadvantage because the squared sound pressure is always positive as a result of the squaring process. The precise method of averaging and the averaging time period must be defined. The short time exponential average sound pressure defined in BS EN 606051:1994 (IEC 651 : 1979) 'Sound level meters' using the F detector-indicator characteristic with a time constant of 125 ms is used to indicate the short time amplitude of sound waves. For long time averaging over multiple events or over time periods of longer than a few seconds, the long time root mean square sound pressure is used with a linear averaging time extending throughout the defined observation time period. For all sounds which are steady over time, exponential and linear

averaging give the same numeric results.

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.

Long time linear average root mean square sound pressure

For any fluctuating sound, the linear average root mean square sound pressure gives the same numerical value as for a steady sound with same amount of physical sound energy at a defined receiver point over a defined observation time period. The linear average root mean square sound pressure is independent of any sound level meter detector-indicator characteristics (see BS EN 60651:1994 (IEC 651:1979) 'Sound level meters'), because the 'mean' is applied over the entire defined observation time period.

Decibels

In environmental noise, decibel measures (symbol dB) are commonly used in any one of three different ways. If necessary, and to avoid any possibility of misunderstanding, it is important that specialist advice should be obtained. 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. The chief advantage of decibel measures is that large ratios can be expressed as relatively small numbers, although whether this remains a real advantage with modern information technology is a matter of some doubt.

The first of the three different ways decibel measures are commonly used is directly, as originally intended, as indicators of ratio. The sound reduction through a partition can be expressed in decibels as the ratio between the incident sound intensity (sound power per unit area) to the transmitted sound intensity (again, sound power per unit area). For example, if the ratio is 100:1, i.e. only 1% of the incident sound intensity is transmitted through the partition, then the ratio can alternatively be expressed as 20 decibels (10 times the number of powers of ten, found by multiplying the logarithm of the ratio (2) by 10).

Secondly, in the case of absolute sound **level**, the ratio is found from the square of the sound pressure (measured in pascals) of the sound being measured divided by the square of a defined reference sound pressure (again, measured in pascals). The use of the word **level** implies that the decibel measure indicates a ratio to a defined reference quantity. The squares are required to convert from a ratio of pressures to a ratio of intensities (an energy or power quantity) to comply with the definition of decibel measures. The reference sound pressure is defined as 20 micropascals in BS EN 21683:1994 (ISO 1683: 1983) 'Acoustics - preferred reference quantities for acoustic levels'. For example, a sound pressure of 1

pascal has an absolute sound level of 94 decibels, calculated from 10 times the logarithm of 1 Pa (squared) divided by 20 μ Pa (squared).

The third common use of decibel measures is to indicate sound power radiated at source, in this case as sound power **level**. For sound power level, the ratio is found by dividing the sound power (measured in watts) of the source being measured by a defined reference sound power (again, measured in watts). The reference sound power is defined as 1 picowatt in BS EN 21683:1994 (ISO 1683: 1983) 'Acoustics - preferred reference quantities for acoustic levels'. For example, a source radiating 1 watt of sound power has a sound power level of 120 decibels, calculated from 10 times the logarithm of 1 watt divided by 1 picowatt.

In addition, decibel measures can be encountered in many other specialist fields. For example, sound intensity (measured in W/m^2) can often be found expressed as sound intensity level using a reference sound intensity of 1 picowatt/ m^2 .

Because of the problems of using logarithms, most acoustic calculations are carried out by first converting decibel measures to their derived SI unit equivalents, completing the calculation, and then converting back to decibel measures at the end. The use of decibel measures often causes more confusion than understanding. The only benefit of retaining decibel measures in the field of environmental noise assessment seems to be the maintenance of continuity with historic practice. Certainly, all criteria used to set targets and limits could equally be defined in terms of the equivalent underlying SI units which the decibel measures merely represent.

L_{max} , 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_{eq} , average sound level

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 L_{eq} 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 L_{10} and the L_{90} have been adopted for particular purposes in the past. The L_n 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*'. The upper and lower limits of the normal auditory frequency range are difficult to define because human auditory sensitivity falls off gradually rather than abruptly at the extremes of the range. The frequency spectrum shows the relative amounts of sound energy present in different frequency bands across the frequency range.

Octave and one-third octave band frequency analysers divide the frequency range into logarithmically spaced frequency bands. The number of frequency bands between 1000 Hz and 10,000 Hz is the same as the number of frequency bands between 100 Hz and 1000 Hz.

Some frequency analysers use linearly spaced frequency bands. The number of frequency bands between 1000 Hz and 10,000 Hz is ten times as many as the number of frequency bands between 100 Hz and 1000 Hz.

All frequency analysers take longer to give a stabilised reading at low frequencies than at high frequencies. This is simply a problem of physics and may need to be taken into account by specialists.

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). For the A-frequency weighting, the relative attenuation is 19.1 dB at 100 Hz and 2.5 dB at 10,000 Hz. The justification for the different frequency and time weightings is given in clause 2.3.3 of the standard as follows; '*In the past, frequency weighting and time weighting have been associated with certain characteristics of the ear. However, recent work has not substantiated these historical associations so that frequency and time weighting characteristics of sound level meters may be considered to be conventional*'.

PNL

The PNdB is derived from the 1/3 octave band SPL's via a complicated procedure requiring tables of A_{noy} values.

Zwicker

The procedure to calculate loudness according to Zwicker is too complex to describe here in detail. Numerous papers have been published by Zwicker himself and several other authors (see [1] for an overview). The basis is that the frequency spectrum is divided into critical bands (expressed in Bark), in which the loudness (in sone) of a sound is determined. This then leads to an overall loudness value.

L_{Aeq} , A-weighted average sound level

The A-weighted average sound level forms the basis of the system of primary Harmonised European Environmental Noise Indicators. It is defined as the long time linear average root mean square A-weighted sound pressure expressed in decibels. The same quantity is defined as the equivalent continuous A-weighted sound pressure level and as the average A-weighted sound pressure level in BS EN 60804: 1994 (IEC 804: 1985) 'Integrating-averaging sound level meters'.

Combined noise sources

For the purpose of environmental noise assessment, 'combined noise sources' describes any situation where two or more of the main categories of noise source described above are present.

Impulse noise

There is no commonly agreed precise definition concerning the impulsive character of a sound. The latest draft of an amendment to ISO 1996-2 contains four possible ways to describe the impulsive character of a sound:

- determination of the difference $L_{Aeq,T} - L_{Aeq,T}$
- measurement with time weighting I;
- measurement with linear peak setting;
- determination of the A_{inc} descriptor.

However, no criterion is laid down for the decision whether one sound is considered to be impulsive and another not. Sometimes this decision is left to the subjective sensation of an exposed person.

annex 6 **References**

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