LIVING WITH L_{eq} IN GERMANY

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1. INTRODUCTION

In Germany, the A-weighted equivalent sound pressure level is generally used for measuring and assessing noise. Depending on the type of noise, time constants of "FAST", "SLOW" or "IMPULSE" are available. When considering the L_{eq}, not only its value is of interest, but also the duration of the time period which was used for the averaging of the sound pressure level. The sound pressure level is averaged separately for day and for night. The day time is defined by the time period from 6 a.m. until 10 p.m. and according to that the night time lasts from 10 p.m. until 6 a.m.

Zoning codes and limit values are very important for the acoustical assessment of noise. In Germany, there are different zoning codes and limit values for different kinds of noise which are determined by standards, instructions and official regulations.

The zoning codes and limit values are also specified separately for day and for night time. They represent A-weighted immission levels that should not, or must not, be exceeded for the time period referred to. However, instead of the measured or calculated equivalent sound pressure level, the rating level will be compared with the zoning codes and limit values. The rating level results from the L_{eq} which will be increased or reduced by corrections for special situations along traffic routes, for impulsive or tonal sounds, and for special time periods. Using these corrections of the L_{eq}, the annoyance of special noise situations should be taken into account.

It is important to realize that the rating level can significantly differ upwards or downwards from the real L_{eq}. The rating level is an evaluation quantity not a measuring quantity.

In the following, the German characteristics of determining the L_{eq} and also the rating level in different noise situations will be described and discussed.

2. DIFFERENT KINDS OF AVERAGED SOUND LEVELS

2.1 L_{eq}

In Germany, the method for averaging sound levels is specified in DIN 45641 "Mittelung von Schallpegeln" - "Averaging of sound levels" [1]. The principle described there is based on a sampling method. Samples of the sound pressure level are taken in fixed time intervals. The samples are energetically averaged at the end of the measuring period. The mean value is called equivalent sound pressure level:

$$L_{eq} = 10 \ \lg \left[\frac{1}{n} \sum_{i=1}^{n} 10^{L_{p,i}/10\mathrm{dB}} \right] \mathrm{dB};$$

where is n : number of samples
$L_{p,i}$: one measured sample of the sound pressure level.

On the premises that the square of the sound pressure level corresponds to the sound intensity I, the equivalent sound pressure level is equal to ten times the common logarithm of the sound energy.

For fluctuating or impulsive noise a sampling rate of at least 5 samples per second is required. Therefore, this method is not appropriate to be carried out by hand. In practice, a number of calculating or integrating sound level meters is available from several manufacturers.

In Germany, measurements of the L_{eq} are generally performed with A-weighting and time constant FAST. L_{eq}s measured with time constant SLOW differ significantly from those measured with time constant FAST only at averaging time periods less than one second. For normal noise they correspond closely.

For impulsive noise or considerably fluctuating noise which is characterised by large variations of the level at short time intervals, the time constant FAST is too long. The actual energy content of the sound begins to be underrated, causing an error of several dB. In this case the time constant IMPULSE should be used.

The time weighting IMPULSE is characterised by a difference between the rise and decrease time constant. The rise time constant at 35 ms is considerably shorter than that at the time constant FAST, whereas the decrease time constant at 1500 ms is considerably longer. This leads to typical slopes in the time history of the sound pressure level. The time weighting IMPULSE consequently reproduces the occurrences concerning the formation of loudness in the human ear, but only in a very loose approximation [2]. Nevertheless, with time constant IMPULSE energy is slightly over-estimated but the effect of noise is covered better.

The areas between the level curves and the x-axis in fig.1 are a measure of the energy content of the noise. The difference of the areas increases as the fluctuation of the level increases. The L_{eq}s diverge in the same way. Therefore, the difference $K_I = L_{AIeq} - L_{AFeq}$ is used as a correction for impulsive noise. The correction for impulsive noise is an important quantity for the formation of the rating level.

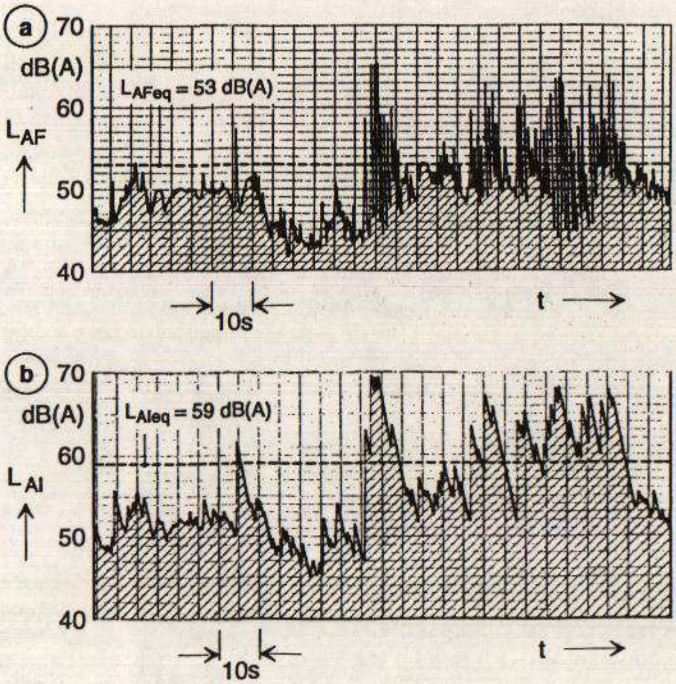

Fig.1 : Time functions of the A-weighted sound pressure level caused by noise from a construction-site.
(a) time constant FAST;
(b) time constant IMPULSE.
Energy equivalent areas hatched.

2.2 L_{AFT}

The most important basis for the assessment of noise situations in Germany is the "TA Lärm" ("technical specification for protection against noise") [3] and the VDI (association of German engineers)-specification 2058 "Beurteilung von Arbeitslärm in der Nachbarschaft" ("assessment of working noise in the vicinity") [4]. These instructions refer to the assessment of sound immissions caused by industrial noise and contain both zoning codes and descriptions of the measuring method.

The measuring method which both specifications dictate for measuring fluctuating noise is called "Taktmaximalpegel-Verfahren". As is shown in fig.2, the measuring time period is segmented into equally long time intervals, so-called cycles. Every cycle has a duration of 5 seconds. For each interval the maximum L_{AFT} of the A-weighted sound pressure level, measured with time constant FAST, is determined. To get the mean value L_{AFTeq} all the maximum levels L_{AFT} are averaged. The level curve in fig.2 is based on the same signal that was used for fig.1a, hence, one can see that the L_{AFTeq} differs from the L_{AFeq} by 6 dB. This value corresponds to the difference found for the L_{AIeq} in fig.1b. This means that the L_{AFTeq} contains the correction for impulsive noise implicitly, and represents effect of noise better than its energy content.

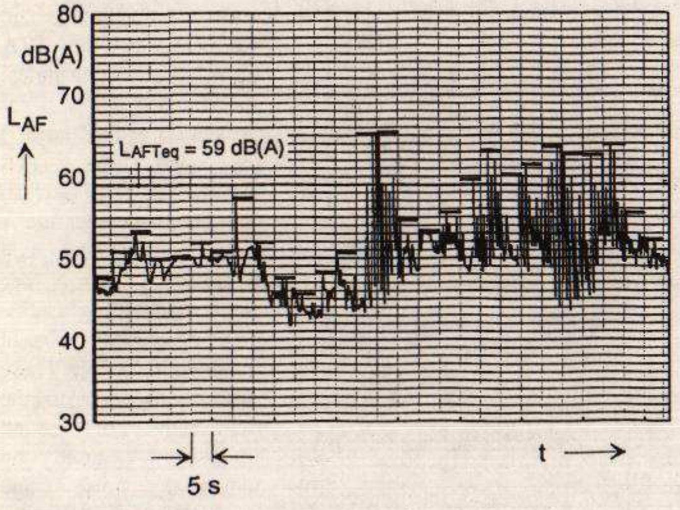

Fig **2**: Deduction of the "Taktmaximalpegel" L_{AFT} from the time history of the A-weighted sound pressure level, measured with time constant FAST (see fig. **1**a)

Consequently the result of the "Taktmaximal-pegel"- method is a single-value comparable to the L_{eq} which follows from the energetic averaging of sample values. But there is a significant over-estimation of peak values of the sound pressure level. Therefore fluctuating or impulsive noise leads to considerably higher values of the L_{AFTeq} than of the L_{AFeq}. Fig.3 shows schematic time histories of the sound pressure level of two sounds with clearly different time-varying.

The upper level curve in fig.3 results from a noise with little fluctuation, whereas the lower one shows that of an impulsive noise. The difference between the L_{ATeq} and the L_{AFeq} for the noise first mentioned comes to 1.5 dB only. On the other hand the level difference for the second noise is 6 dB.

The 5 seconds time interval allows evaluation of measurements by hand, particularly when the time function of the sound pressure level was registered with a level recorder. There are of course level meters which are able to make the evaluation automatically.

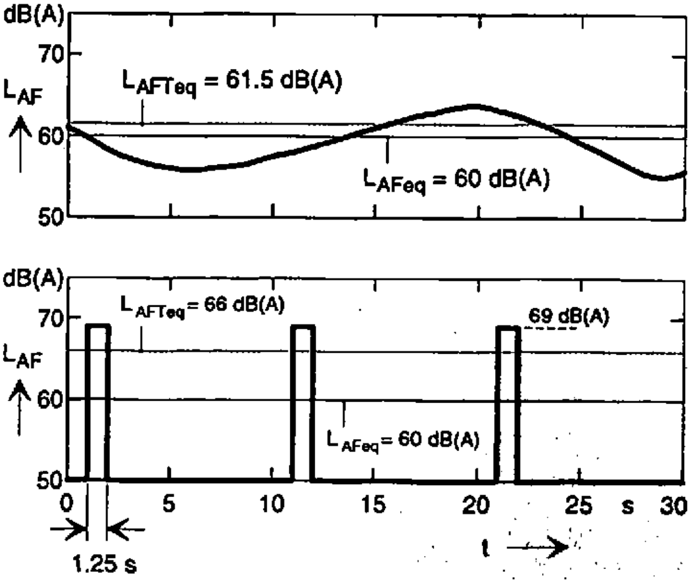

Fig. 3: Two examples of noise with the same equivalent sound pressure level L_{AFeq}, but different "effective level" L_{AFTeq}. The difference is caused by the different temporal structure of the noise.

3. FORMATION OF THE RATING LEVEL

As mentioned in the introduction, in Germany the rating level instead of the L_{eq} is used for the comparison with zoning codes and limit values. In the following, it will be shown how the rating level for different noise situations can be obtained using measured or calculated equivalent sound pressure levels.

3.1 Road and railway traffic noise.

Starting point for getting the rating level is the L_{Aeq} which exists at the site of immission during day time from 6 a.m. until 10 p.m. and night time from 10 p.m. until 6 a.m. The L_{Aeq} will be obtained by special methods of calculation based on results of sound level measurements and on investigations of traffic. For the calculation of the L_{Aeq} the following non acoustical quantities are allowed:

Tab. 1:

road	railway
number of vehicles	number of trains per day and per night
proportion of vans	sort of train
speed limit	proportion of disk brakes
gradient of the road	length of the trains
surface of the road	average speed of a train
	properties of the rail

If the site of immission belongs to the effective range of a street crossing with traffic lights, the rating level will be obtained by an increase of the L_{Aeq} for the running traffic by 1, 2 or 3 dB, depending on the distance between the crossing and the site of immission within a range of 100m.

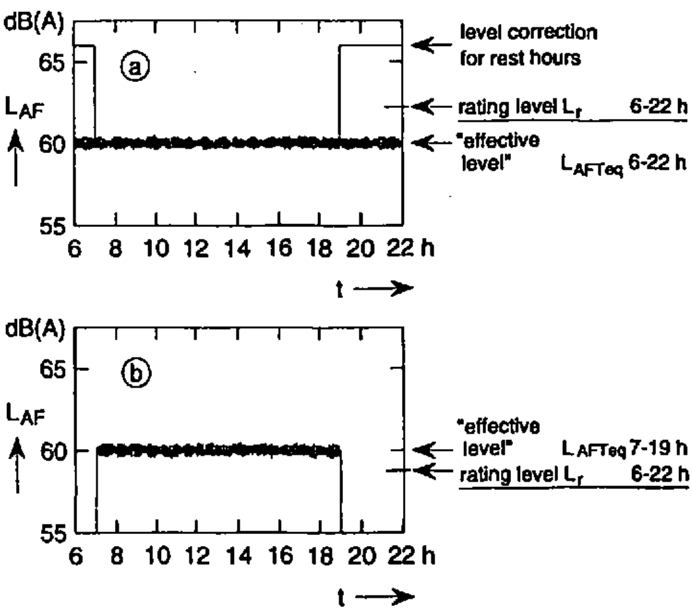

Fig.4 : Effect of different working-periods on the rating level
ⓐ working-period: 6 - 22 h
ⓑ working-period: 7 - 19 h

The rating level for noise caused by rail vehicles is the L_{Aeq} with a reduction of 5 dB. This correction of the average level takes into consideration that the annoyance of railway noise is significantly lower than that of traffic noise for the same L_{Aeq} [5].

3.2 Industrial noise

The rating of industrial noise is decribed in the "TA Lärm" and the VDI-specification 2058. The VDI-specification 2058 contains some important corrections of the L_{Aeq} for the determination of the rating level:

1. Correction for impulsive noise K_I. This takes into consideration the increased inconvenience of impulsive noise. The value is 3 or 6 dB. If the "Taktmaximalpegel" L_{AFT} is measured, no correction is necessary because the measuring method itself takes care of that (see 2.2).
2. Correction for tonal sounds K_T. If the noise contains single tones which are clearly audible, 3 or 6 dB will be added to the L_{eq} because of the increased annoyance of tonal sounds.
3. Correction for rest hours K_R. During day time which lasts from 6 a.m. until 10 p.m., higher zoning codes are valid. Nevertheless, the need for quiet will be considered between 6 and 7 o'clock in the morning and also between 7 and 10 o'clock in the evening. The L_{eq} of industrial noise which occures during these rest hours will be increased by 6 dB. A limitation of the working period from 7 a.m. to 7 p.m. can cause a reduction of the rating level by 3.6 dB in maximum. This is demonstrated in fig.4.

It is important to note that there is no correction for rest hours for sound immissions caused by traffic noise.

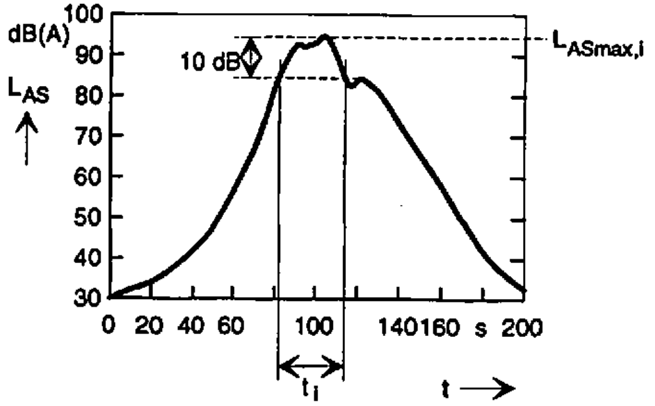

Fig. 5: Time function of the A-weighted sound pressure level, measured with time constant SLOW, during the fly-by of a jet plane.
$L_{ASmax,i}$: maximum sound pressure level of this event;
t_i : effective duration of the fly-by.

3.3 Air-traffic noise

The calculation of the L_{eq} for air traffic noise should be based on the single event level SEL or L_{ASX} [6], [7]. This level is especially suitable as homogeneous measure and evaluation quantity of single and short events of noise. During one measurement the sound pressure level will be integrated during the time interval t_i which indicates the time period for which the sound pressure level exceeds a given threshold. Afterwards, the L_{ASeq} determined for the time interval t_i, will be converted to the L_{ASX} for a time period of 1 second. It is:

$$L_{ASX} = 10 \ \lg \left[\frac{1}{1sec.} \int_{t_i} 10^{L_{pAS}(t)/10dB(A)} dt \right] dB(A);$$

where is t_i : integration time (10 dB down time)

$L_{pAS}(t)$: A-weighted sound pressure level, time constant SLOW.

Fig.5 shows a typical time function of the sound pressure level of a fly-by, measured with time constant SLOW and A-weighting. The threshold for integration is 10 dB below the maximum of the sound pressure level. The equivalent sound pressure level for the rating period results from the conversion of the L_{ASX} values of all single events to the rating period and their energetic summation. It is:

$$L_{ASeq} = 10 \ \lg \left[\frac{1sec.}{T} \sum_j 10^{L_{ASX,j}/10dB(A)} \right] dB(A);$$

where is T : reference time period in seconds

$L_{ASX,j}$: single event level of one fly-by.

The reference time period T is dictated by the German regulation for air-traffic noise [8]. The reference time period is defined as that six months of the year which show most of the traffic.

4. REFERENCES

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