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Methods For Calculating LAFmax Using The Nordic Prediction Method, Nord 2000 And Cnossos-EU

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ABSTRACT

In Sweden the use of maximum a-weighted sound level (LA_{Fmax}), in combination with equivalent a-weighted sound level over 24h (L_{Aeq24h}), has been used for noise regulation for many years. The regulation was turned into legislation in 2015 for new housing development plans. The maximum level gives a good indication of sleep disturbance for residents in exposed dwellings, especially if combined with number of loud passages or events. In areas with little traffic the equivalent level can be very low, whereas the maximum level just depends on an individual vehicle rather than on the number of vehicles. The Swedish legislation defines maximum noise level as "the loudest vehicle, with time weighting 'Fast', calculated as a free field value". When calculating noise levels from road or rail traffic, there is no knowledge of individual vehicle properties. In the prediction methods used in Sweden, the calculation of maximum level is therefore based on statistical data such as the standard deviation of measured sound levels for each vehicle type at a certain speed. In the current paper some different methods to calculate maximum noise levels are presented, using Nordic methods as well as the common Cnossos-EU method, as well as their impact on results.

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1. INTRODUCTION

In Sweden an Action Plan against Noise [1] was issued as an official report of the Swedish government in 1993, based on a comprehensive body of research on noise and its effects, with Professor Tor Kihlman as appointed special investigator. The Action Plan recommended the use of equivalent a-weighted sound level over 24h (L_{Aeq24h}) in combination with a-weighted maximum noise level as a descriptors of the noise and corresponding exposure. The choise of these measures was based on their wide use and simplicity, but also the good correlation with effects on humans. In the case of maximum level, good correlation had been found with sleep disturbance in the form of icreased number of awakenings, but there was also support for that the difference between background noise level and levels of isolated auditory events as well as number of events was important factors. The use of equvalent level over 24 hours in combination with maximum noise level was adopted as measures for community noise guidlines and restrictions. More recently similar results have been found in complementary analyses of data from the DEUFRAKO-RAPS study [2] where equivalent level was found to be insufficient for predicting awakening potential from railway noise. The results from the DEUFRAKO-RAPS study was also combined with results from other simlar studies in the part of the recently publshed WHO noise guidlines that concerned effects of noise on sleep [3] where an odds ratio of 1.3 was found for road, rail and aircraft noise, and functions for predicting awakening potential from noise has been suggested based on maximum noise levels:

$$Road: -3.3188 - 0.0478\, L_{ASmax} + 0.0037 L_{ASmax}^2 \tag{1}$$

$$Rail: -1.7768 - 0.0529\, L_{ASmax} + 0.0033 L_{ASmax}^2 \tag{2}$$

$$Air: -3.0918 - 0.0449\, L_{ASmax} + 0.0034 L_{ASmax}^2 \tag{3}$$

In general the maximum level appear to be an important measure for predicting certain effects of noise on humans. In most cases noise exposure is calculated using noise prediction models, and to predict effects related to maximum levels there need to be a valid method implemented for calculating those values. In this paper we present some issues that arise when using the statistically based methods proposed for calculating maximumn noise level from road traffic within the Nordic Prediction Method [4] and in the Nord2000 prediction model [5], in the context of the Cnossos-EU prediction method [6].

2. CALCULATING MAXIMUM LEVEL

2.2.1. Definition of maximum level

The convention for maximum noise level is that it can be evaluated with a 1s time constant, denoted "slow" (L_{ASmax}), or a 0.125s time constant, denoted "fast" (L_{AFmax}). These measures are mainly based upon technical properties of measurement equipment, where the time constant is a property of the instrument. Thus the definition of maximum a-weighted noise level is the level measured by an instrument with a certain sertting. An equally distinct definition for calculated maximum a-weighted noise level is more difficult to find. When calculating noise from road traffic, the prediction methods mostly contain functions adopted from empirical data, so that the source strength always will be the same for a certain vehicle type at a certain speed etc. This will be reliable for average levels such as $L_{Aeq,24h}$ or L_{DEN} where the traffic flow can be seen as averaged oven 24h or within the respectiv periods of day, evening and night. For maximum level additional knowledge of the traffic is needed, since the measured maximum level depends on a single vehicle. Two different ways of calculating maximum levels are suggested for the Nord2000 prediction model [5]. These are based on the assumption that the spread of maximum noise level of individual vehicle passages is normally distributed, and use the mean maximum level and the standard deviation from a large number or measured individual passages.

$$L_{max5\%} = \bar{L}_{AFmax} + 1.65\sigma \tag{4}$$

$$L_{AFmax,n} = \bar{L}_{AFmax} + P(100\frac{n}{N})\sigma \tag{5}$$

Equation 4 is a way to calculate to level which is exceeded by 5% of the vehicles and Equation 5 is a way to calculate the level that will be exceeded by five vehicles. These two ways of calculating maximum level give different results from each other and are also different from what would be measured from a real traffic flow. A traffic flow simulation was performed to visualize the different behaviour of measured and calculated maximum level.

2.2.2. Simulating traffic flow

In order to investigate effects of random variations in traffic flow, a so-called Monte-Carlo simulation was performed using the Cnossos-EU prediction model [6] for one single vehicle of each category as a basis upon which variations in traffic flow was applied. The Monte-Carlo simulation was performed by assuming that the traffic is two independent random processes, one for each lane. The time gap between vehicles was assumed to be Poisson distributed, but with a constraint so that no vehicles in the same lane are closer than two seconds from each other. Distance to the center of the road was set to 50 m, and the total road width was 13 m. The road surface was modeled as hard, and the surrounding flat landscape as ground type “C” with a receiver height of 2 m. Each vehicle passage was modeled as a line source as described in Cnossos-EU, and the sound power level was taken for category 1 for all light vehicles. For heavy vehicles 50% were assumed to be category 2 and 50% category 3. The speed was assumed constant at 50 km/h. In order to model the random variation between vehicles data from the Nordic Prediction Method [4] was used, which proscribes that the maximum level variation is normally distributed with a standard deviation of 2.7 dB for light vehicles and 4.1 dB for heavy vehicles at 50 km/h. For six different levels of traffic flow (20, 50, 100, 200, 500 and 1000 vehicles per hour), 500 simulations of the noise level at the receiver where performed and the data was used to calculate the maximum noise level as described in the Nord2000 prediction method [5] (see Figure 1).

Here the traffic flow simulations represent what would be measured on 500 different occations. It can be seen that the level exceeded by 5% of the vehicles underestimates the measured (simulated) maximum level for low traffic flows and underestimates it for high traffic flows. The fifth loudest vehicle follows the increase in measured maximum level with increased traffic flow, but since heavy vehicles are (modeled as) louder than light vehicles, but only constitutes a fraction of the total number of vehicles, there is a step in the curve when the flow becomes large enough to include at least one heavy vehicle. This

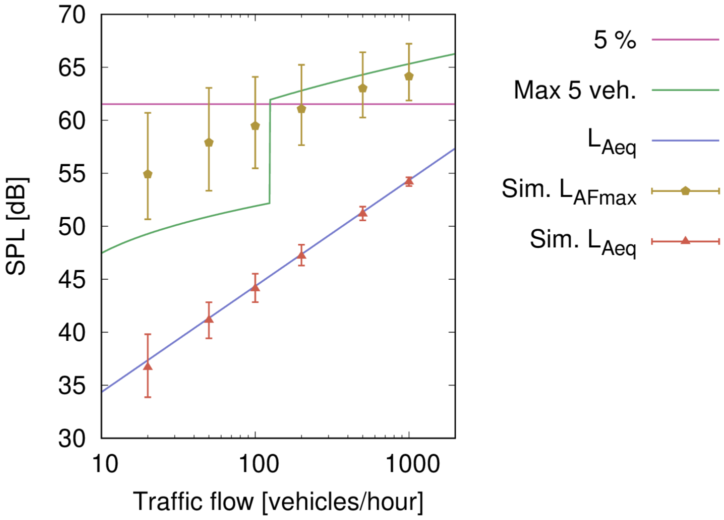

Figure 1: Illustration of theoretical maximum levels and simulated measurements of the maximum level L_{AFmax} (beige) and of the equivalent level L_{Aeg24h} (red). The theoretical levels are the maximum level exceeded by 5% of the vehicles for a single undisturbed passage (magenta), the level of the fifth noisiest passage for a single undisturbed passage (green) and the equivalent level LAeq (blue) for comparison. Simulated errorbars show the range from the 5 percentile to the 95 percentile in the 500 Monte Carlo runs for each traffic flow.

could occur for some measurement occasions as well, but over as many as 500 occasions the effect is insignificant.

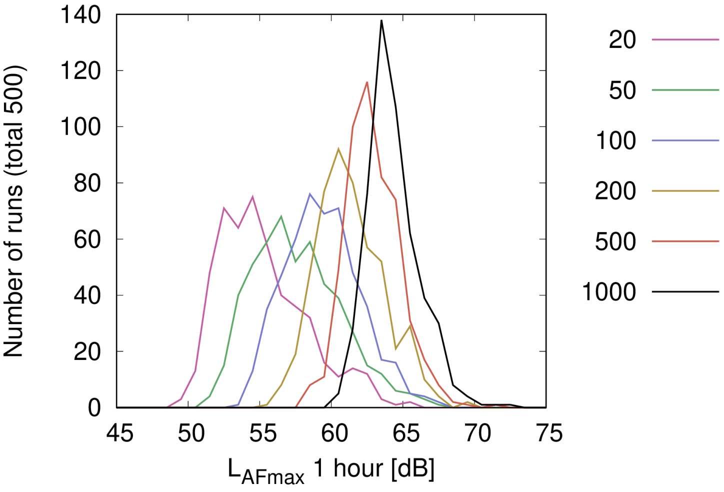

Figure 2: Histogram of the maximum level LAFmax for 500 one hour simulations. Hourly traffic was simulated from 20 to 1000 vehicles per hour. Histogram bins are 1 dB intervals.

The complexity in calculating the maximum noise level can also be visualised through histograms over the spread of calculated maximum levels from the 500 Monte-Carlo runs (see Figure 2). The random variations of the simulations correspond to situations for low traffic flows where in one case there are two vehicles that happens to meet close to the receiver and in another there is a large distance between all vehicles, or in one where there was a very noisy vehicle and another where all vehicles were quieter. The spread of the simulated maximum levels is as can be seen large for low traffic flows, which is due to that one single loud vehicle will have a large impact. With the higher traffic flows the probability for a loud vehicle increses as well as the probability for two vehicles meeting close to the receiver, mainly because of the larger number of vehicles passing during the hour, and consequently the median maximum noise level increases with increased traffic flow.

For a simulated maximum level of 55 dBA, the 5% level is roughly 60 dBA and the fifth loudest vehicle level is roughly 50 dBA. Using Equation 1 this corresponds to awakening potentials of 3.54, 5.24 and 7.13 respectively, which emphasizes the effect of choice of calculation method for maximum noise level.

3. CONCLUSIONS

Maximum noise level is a useful measure as a complement to the eqivalent level over 24h or the adjusted day-evening-night measure. Measuring maximum level is relatively straightforward, as the loudest vehicle passage will be the determining one, but calculating a meaningful maximum level is somewhat more complicated and demands knowledge about statistical distribution of noise levels from vehicles. The current paper presents an overview of some of the aspects involved in calculating a maximum noise level from road traffic, and the results point to the need for a generally accepted definition of a calculation method for maximum level that can be used by policy makers.

4. ACKNOWLEDGEMENTS

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