Bergen, Norway

BNAM 2010

May 10-12

Monitoring of noise emission levels of individual road vehicles

Truls Berge and Asbjørn Ustad

SINTEF ICT, Department of Acoustics, NO-7465, Norway, truls.berge@sintef.no

A monitoring station has been developed to measure the pass-by noise emission levels of individual vehicles in normal traffic. The monitoring station measures the noise levels, the speed of the vehicles, classification (based on length) and direction of travel (lane). In addition, a weather station is used, including a surface detector (wet/dry). This means that all emission levels can be related to meteorological parameters such as temperature, wind direction/speed, and if the surface is wet or dry. In addition to individual noise levels (L_{AmaxF} and L_{Ae}), 1 hr/24hrs L_{Aeq}/L_{den}-levels and 1/3rd octave band L_e frequency spectra from 25 Hz to 10 kHz are also measured.

As a first test of the monitoring station, over 34 000 vehicles have been monitored at one location only; a dual lane road with posted speed 60 km/h. The analysis of the data makes it possible to compare the noise contribution of different categories of vehicles to the overall equivalent levels, the influence of a wet road surface, etc. In addition, a simulation has been done, to study the effect of removing the most noisy vehicles away from the fleet, for example all passenger cars with levels above a certain limit. As a first test, removing all passenger cars with emission levels above 85 dB(A) (about 2-4% of the passing cars at this location) will only reduce the 24hrs equivalent levels in the region of 0.5 – 1 dB(A). However, if the limit is set to 80 dB(A) (about 22-25% of the cars exceeding this level), a reduction of 3-4 dB(A) can be achieved. Preliminary results show that a wet surface gives an increase in spectral levels only above 1 kHz for passenger cars and only increase the overall levels in the area of 1-2 dB(A).

The study was part of the EU-project SILENCE.

1 Introduction

Noise reduction at source is regarded as the most effective measure to reduce traffic noise. Such measures can be applied to the individual vehicle, by reducing power train related noise and/or the use of more silent tyres/road surfaces. Another measure to influence the noise emitted by vehicles is the behaviour of the traffic, which may be governed through different traffic management systems. Such systems can influence the vehicle speed, acceleration/deceleration rates, composition of the fleet, etc. Examples are traffic calming schemes, speed cameras, restrictions/bans on heavy goods vehicles, "green" driving instruction, etc.

The noise of individual vehicles can be reduced by more stringent noise emission regulations for the total vehicle itself and for the tyres separately. The challenge with such regulations is the time needed for obtaining the effect of reduced noise limits, especially for L_{Aden}/L_{Aeq}- levels. The average lifetime of a passenger car is around 18-22 years (at least in Norway). For tyres, the circulation time is much shorter so the effect of more stringent limits will be more efficient here.

However, for all different measures that can influence the emitted noise from a vehicle, it is important to monitor or verify the effectiveness of such measures. As part of the EU-project SILENCE, SINTEF has developed a monitoring system that allows road authorities or local municipalities to monitor long time effects of both international regulations for vehicles and tyres, as well as the effect of local traffic management schemes[1]. In this paper, some results from initial testing of the monitoring system are presented.

2 Principle lay-out of the monitor

The monitor consists of basically 3 separate parts:

1) Traffic registration system
2) Acoustical registration system
3) Meteorological registration system

2.1 Traffic registration system

The traffic registration is done by using a commercial available system, Datarec7 Signature (Dr7), from the company AADI in Norway. The Dr7 is based on 4 inductive loops within the road surface, which counts the traffic, identifies the lane, driving direction, vehicle speed, etc. Dr7 has a vehicle classification system which can either be based on inductive pattern recognition or on the vehicle length. In these measurements, the classification was based on length only. The vehicles are classified in 5 different classes, see table 1.

Table 1: Vehicle classes

Class	Description
1	Motorcycle, scooter (1.85…2.39m)
2	Passenger car, light vehicle (2.40…5.10 m)
3	Truck ≤ 3 axles (5.11…10.00m)
4	Bus ≤ 3 axles (10.01…12.50 m)
5	Truck > 3 axles (12.51…25.00 m)

In addition to these 5 classes, there is a Class 0 for unclassified vehicles.

2.2 Acoustical registration system

The acoustical system consists of a 2 channel PC-based sound level meter system developed by SINTEF. The system can show all measured levels in real time and the time history of levels are continuously presented. An outdoor microphone system (microphone and preamp) from Norsonic AS was connected to the soundcard in the PC. In addition, a special graphical user interface (GUI) was developed for the monitoring system.

One of the microphones is used for measurement of acoustical parameters such as L_{AmaxF}, L_{Aden}, L_{Aeq1h}, etc. The other microphone can be used for detection of studded/non-studded tyres on passenger cars.

The main features of the acoustical measuring system are as follows:

The system continuously measures statistical acoustical parameters, such as L_{Aden}, L_{Aeq24h}, L_{Aeq1h} and $L_{AmaxF1h}$. All these data are related to the general traffic flow.

In addition, it is possible to measure the noise emitted by each vehicle. The noise signature level (level as a function of time) is continuously monitored. For each pass-by, a maximum level is registered. An algorithm has been developed to locate the maximum level within 3s before or after the time of the detection of the vehicle pass-by. When the maximum level has been found, the time till the level at each side of the maximum is more than 6 dB(A) down, is determined. If this is within predefined values, and there is no vehicle in the other lane at the same time, the event is regarded as a single vehicle pass-by, not acoustically influenced by other traffic. Then the L_{AmaxF} and L_{Ae}-levels, and the 1/3rd octave band L_e levels from 25 Hz to 10 kHz are saved. The system allows longer heavy trucks to be identified acoustically, even if they may have several maxima during a pass-by.

2.3 Meteorological registration system

The meteorological registration system is a commercial available system, with a multiple choice of different sensors.

For these measurements, the following sensors were chosen:

- air temperature
- wind speed
- wind direction
- air humidity

In addition, the Road Condition Sensor 3565E from AADI was connected. This sensor gives the road surface temperature, indication on wet/dry surface, snow coverage and the salinity (freezing point) of the moisture on the surface. The latter data was not used during the test period. All the sensors were connected through the Data Logger 3660 from AADI, which has input for 18 sensors.

3 Test site and measurement conditions

The test site chosen for the measurements was a dual lane rural road (Osloveien, Rv715) within the city Trondheim. The traffic volume is approx. 15 000 ADT, with 10% heavy duty vehicles. The posted speed is 60 km/h. The location was chosen because it already had available inductive loops within the road surface. The road surface type is SMA 0/16 from 2003. The microphone is located 7.5 m from the centreline of the road and at a height of 3.5 m.

A total of 34498 approved vehicles (according to the acoustical criteria) were measured in the period 25.8 – 29.9.2008. The air temperature varied from +5 to + 22 °C. During the period, several days with rain/wet surface were included.

3.1 Measurement results

Table 2 shows the number of vehicles measured in the 5 classes, as defined in table 1.

Table 2: Number of vehicles measured

Class	**Vehicle type**	**Number of vehicles**
1	Motorcycle, scooter	441
2	Passenger car, light vehicle	29292
3	Truck ≤ 3 axles	2930
4	Bus ≤ 3 axles	411
5	Truck > 3 axles	1424

During the measurement period, we only had 5 complete days and nights with a dry surface, giving a total of 7084 approved pass-bys. Figure 2 shows L_{Amax}-levels for this number of vehicles on a dry road surface.

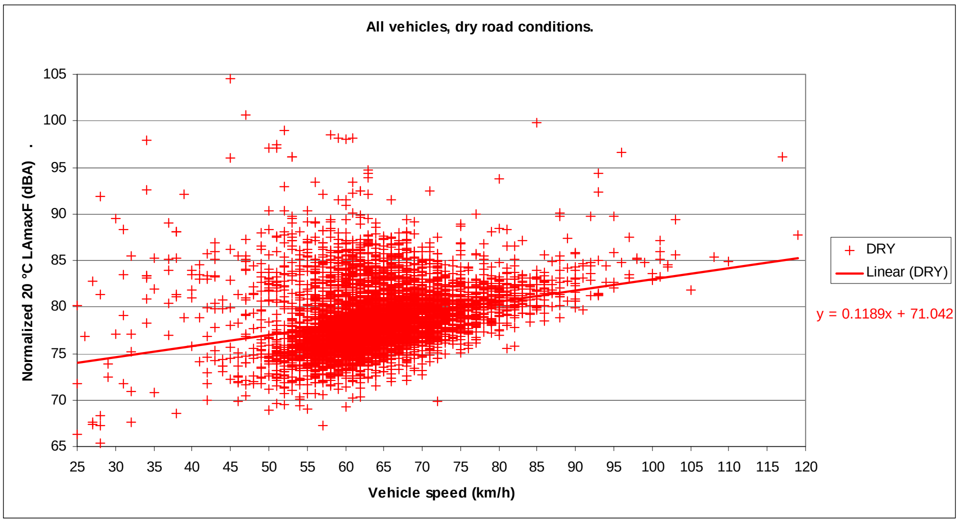

Figure 2: L_{Amax}-levels for all categories on dry surface

As the figure show, there is a considerable spread in noise emission levels; about 40 dB(A) (65-105 dB(A)). Another feature of the results at this particular location is the wide spread in levels at low speeds. This is probably caused by the fact that close to the monitor, there is a crossing to a small local road, resulting in a number of vehicles passing the microphone accelerating at low speeds from the crossing. To avoid this influence, we have included only vehicles in the speed range of 50 to 70 km/h for further analysis. In table 3, the average levels (L_{Aeq24h}/L_{Aden}) are shown for each of the days with complete set of measurements on a dry road. All levels have been normalized to 60 km/h (30 log(v)) and to + 20 °C, by using a correction formula of – 0.05 dB/°C.

Table 3: All classes, normalized to 60 km/h and + 20 °C

Day	N all classes	LAeq24h dB(A)	LAden dB(A)
Thursday	1371	68.1	73.6
Friday	1328	68.1	73.4
Saturday	1853	68.1	74.0
Tuesday	1316	67.7	73.9
Wednesday	1216	67.4	73.2

As table 3 show, the average equivalent levels are almost identical (within 1 dB(A)).

3.2 Contribution of different classes

For the 5 complete 24hrs periods with dry surfaces, an analysis of the contribution from different classes has been performed. In this paper, only the analysis of the influence on the $L_{Aeq24hr}$ is presented.

During the 5 days, the different classes of vehicles have a different contribution to the overall $L_{Aeq24hr}$ –level, depending on the percentage of the total fleet. In table 4, the average composition of the fleet of the 4 working days are shown (did not vary much) along with the composition of the fleet on the Saturday included in the database.

Table 4: Traffic volume of different classes

Class	Type	Working day %	Saturday %
1	MC/Scooter	1.7	1.1
2	Passenger car/light vehicle	81.1	92.3
3	Truck ≤ 3 axles	10.5	4.7
4	Bus ≤ 3 axles	1.8	0.7
5	Truck > 3 axles	4.9	1.2

Based on the individual SEL-value of the pass-by of each separate class of vehicles, the contribution to the total energy based value can be calculated. The results are shown in table 5. The values can also be seen as the amount of reduction in the $L_{Aeq24hr}$ –level in dB(A) one can achieve by omitting the individual class from the traffic (at this specific location).

Table 5: Contributions to the total $L_{Aeq24hr}$-levels

Class	Type	Working day dB(A)	Saturday dB(A)
1	MC/Scooter	0.3	0.1
2	Passenger car/light vehicle	4.4	10.2
3	Truck ≤ 3 axles	0.8	0.2
4	Bus ≤ 3 axles	0.8	0.2
5	Truck > 3 axles	0.5	0.1

As can be seen from these results, the main contribution to the overall level comes from the passenger cars/light vehicles. Especially on the Saturday traffic, the heavy trucks/buses and the motorcycles has a very little influence on the $L_{Aeq24hr}$ –levels. At this specific location, the ban of heavy vehicles (> 3 axles) will only reduce the $L_{Aeq24hr}$ –level with approximately 0.5 dB(A) on working days and 0.1 dB(A) at a weekend day.

4 Effect of reducing L_{Amax}-levels

One of the tasks of introducing more stringent noise emission limits is to reduce the maximum noise levels from vehicles. In addition, local regulations like periodical noise control/road side control can also be a tool to reduce these levels. To study the effect of reducing maximum levels, a theoretical calculation has been made, where all Class 2 vehicles (light vehicles) with noise levels above 90, 85 or 80 dB(A) have been removed from the population. In table 6, the influence on the $L_{Aeq24hr}$ –levels is shown, together with the % of vehicles removed at each of the 3 scenarios. The statistics is based on the data shown in table 3.

Table 6: Reduction of $L_{Aeq24hr}$-levels at different scenarios

Scenario	Removing vehicles with L_{Amax}-levels above	% of vehicles	Reduction of $L_{Aeq24hr}$
1	90 dB(A)	< 1 %	~ 0.5 dB(A)
2	85 dB(A)	3-4 %	1 -1.5 dB(A)
3	80 dB(A)	22-26 %	3-4 dB(A)

As table 6 shows, one has to "remove" about 25 % of the vehicles with the highest maximum noise levels, to be able to achieve a significant reduction (3-4 dB(A)) of the equivalent noise levels. At least this is the findings at this specific location, and it needs to be confirmed for other locations/traffic situations as well.

5 Influence of wet/dry surface

To study the differences in noise levels on a complete wet and dry surface, we have compared two days with similar traffic load and using the category class 2 only. Figure 2 shows the normalised sound spectra from light vehicles during a wet and dry period. The difference in sound levels is only occurring at higher frequencies (above 1.25 kHz). In table 7, the differences in L_{Aeq24h}/L_{Aden}-levels are shown.

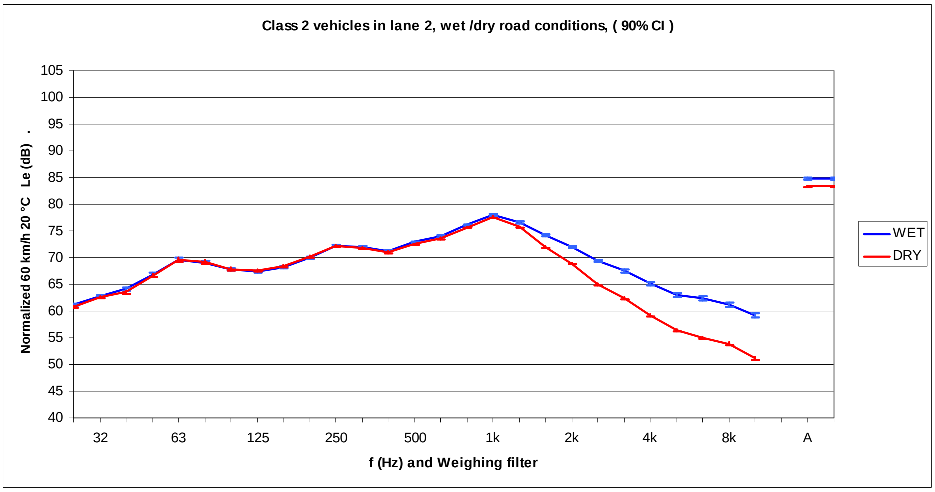

Figure 2: Class 2 vehicles on wet/dry road surface

Table 7: Class 2, Normalised to 60 km/h, differences in wet/dry surface

Dry/Wet	N class 2	$L_{Aeq24hr}$, dB(A)	L_{Aden}, dB(A)
Dry	811	64.5	69.4
Wet	742	65.0	70.8

As these results indicate, there is only a small difference in the equivalent noise levels on a completely wet and dry surface. It is explained by the differences in frequency spectra, where the wet surface only significantly differs at frequencies above 2-3 kHz which is reduced by the A-weighting. The differences in figure 2 above 1.25 kHz are somewhat higher than the corrections proposed in the NORD2000 prediction model[2].

6 Acknowledgement

This project has been partly supported by the Norwegian Research Council, within the research program "Environmental Noise" and partly within the EU-project SILENCE, WP H.

References

[1] T.Berge, Monitoring of road vehicles in-use. Results from testing of measurement equipment.
SINTEF Memo 90E230/TB, 2008-01-04.

[2] H.G.Jonasson, Acoustic Source Modelling of Nordic Road Vehicles. SP Rapport 2006:12, Energy Technology, Borås, 2006.