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Environmental impact of noise from mobile outdoor equipment

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As part of an evaluation study of European Directive 2000/14/EC relating to the noise emission by equipment for use outdoors, an environmental impact assessment was required to investigate the need for new or tighter noise limits. In contrast to other environmental noise sources, the operating location of outdoor machines is not fixed. As conventional environmental noise mapping could not be used for this purpose, a specially adapted environmental indicator was developed. This indicator takes account of the following factors: typical average sound power level of the machine, sound character (tonal / impulsive / intermittent), day/night operation, typical areas of use, annual duration of operation and numbers of equipment in use in Europe. The numbers of people affected were assessed by assuming population densities typical for the areas of use and by counting the numbers of affected inhabitants within each 5 dB wide noise impact contour of a noise map. This resulted in distributions of the numbers of exposed inhabitants as a function of noise impact classes that were characteristic of the different types of environment (urban, suburban, rural etc.). The newly developed environmental indicator is a relatively simple quantity taking all relevant factors of noise impact and annoyance into account.

1 Introduction

Within the framework of the NOMEVAL project [1], [2] an evaluation study of European Directive 2000/14/EC [3] relating to the noise emission of equipment for use outdoors was executed. As part of this study an environmental impact assessment was required to investigate the need for additional noise limits or tightening of the existing limit values. The characteristics of outdoor equipment noise are fundamentally different from transportation noise in terms of source location, operating time and duration and propagation conditions between source and receiver. Some types of equipment (e.g. construction equipment) will operate in a small area for a limited period of time and produce high noise levels during that period. Other types (e.g. municipal service vehicles and horticultural machinery) will operate for short periods of time at regular intervals. The source locations may be very close to dwellings and the sound may be amplified by reflections against surrounding buildings in courtyards, street canyons etc. Moreover, an assessment of the environmental impact and noise annoyance of a certain type of outdoor equipment would require not only a local noise impact computation, but also an extrapolation of these figures to a European level to take account of the varying conditions of use in the different member states.

Therefore a special approach was needed to describe the environmental impact of outdoor equipment. For this purpose a new environmental noise indicator was developed that takes account of the average noise level of the machines in question, the typical duration of use, the character of the sound, the typical working environment, and the penetration of a type of machine into the markets of the member states or into society in general.

2 Environmental Impact indicator for outdoor equipment noise

2.1 Concept

A newly developed environmental noise impact indicator EI was proposed for the purpose of the evaluation study that takes into account several significant parameters affecting the exposure and perception of outdoor equipment noise in various surroundings. After discussion of these parameters in the sections 2.2 and 2.3 the Environmental Impact indicator will be presented in section 2.4.

2.2 Rated sound power

The first input parameter for the environmental indicator is the average guaranteed sound power level $L_{WA,g}$ as measured for each type of machine. Next, the average rated sound power level $L_{WA,rated}$ is deduced by applying level adjustments to take into account human perception of sound. Adjustments are taken into account for evening and nighttime use, tonal and/or impulsive sound components and the typical sound character due to intermittent use. The adjustment for tonal or impulsive noise is consistent with ISO 1996 [4], [5]. Also an adjustment in dB is applied where considered appropriate, to take into account the differences between the typical field operating conditions and the operating conditions according to the test code. Finally, the use of the equipment over a year has been estimated (number of months in use, number of days per month in use and minutes per day in use) resulting in a year averaged equivalent rated sound power level $L_{WA,rated,yeareq}$:

$$L_{\mathrm{WA,rated,yeareq}} = L_{\mathrm{WA,guaranteed}} + C_{\mathrm{evening/night}} + C_{\mathrm{tonal/imp}} + C_{\mathrm{intermittent}} + C_{\mathrm{opcon}} + 10\lg\left(\frac{n_{months} n_{days} t_{dayuse}}{364 \cdot 24 \cdot 60}\right)$$

where

n_{months}	number of months per year in use;
n_{days}	number of days per month in use;
t_{dayuse}	minutes per day in use;
$C_{evening/night}$	adjustment for evening/night use (0 or 5 dB);
$C_{tonal/imp}$	adjustment for tonal and/or impulsive sound character (0 or 5 dB);
$C_{intermittent}$	adjustment for sound character due to intermittent use (0, 3 or 6 dB);
C_{opcon}	adjustment for difference in operating condition between normal use and testing conditions (0 or 3 dB).

2.3 Typical sound immission in Europe

Outdoor equipment is used in various surroundings depending on its function. To estimate the environmental impact of the equipment in Europe, at least in a relative way, the resulting sound levels in typical surroundings and the number of people experiencing those levels have been computed. Combining the resulting sound levels with the corresponding percentage of people affected, taking into account the number of equipment used within Europe, gives the (relative) environmental impact level for each type of equipment.

For the typical surroundings five situations were chosen:

A. Gardening equipment for private use, characterised by three typical (sub)urban environments;

B. Horticultural equipment for professional use, characterised by two typical urban environments;

C. Municipal services, characterised by three typical urban environments;

D. Small and large construction sites, characterised by four (sub)urban environments;

E. Shopping centres, characterised by three urban environments;

F. Rural areas.

A small number of equipment is at least partly used also in rural areas, such as farmland, woods, ski tracks and ski slopes or industrial areas. For the impact, those types of equipment only need to be considered as far as they are used within urban areas. This is effectively done by characterising the rural areas in an equivalent way by only a few inhabitants at a typical distance of 100 to 200 m, the exact numbers being irrelevant in this way.

As typical examples of the various urban surroundings, several areas in the city of Delft were chosen. With the noise impact computation model URBIS (TNO), the sound levels in the vicinity were calculated for a typical position of each equipment type in those areas, and the number of people affected at each level (in 1 dB steps). The noise modeling was done for a fictitious source with a reference sound power level of 100 dB(A). The figures 1 and 2 give examples for some types of surroundings with the corresponding level distributions. The urban areas were chosen from Google-maps and converted into geographical input data-files.

The resulting distributions of inhabitants in each situation (see figure 3) were then shifted for each type of equipment in accordance with the appropriate $L_{WA,\ rated,\ yeareq}$ giving the distribution $D_{equip,situ,i}$. This distribution is normalized by the total number of inhabitants considered in the noise mapping procedure. The calculations were performed in 1 dB steps, the final distribution is based on sound level classes of 5 dB.

Fig 1 – Example of a suburban area and its corresponding noise map for a fictitious sound source.

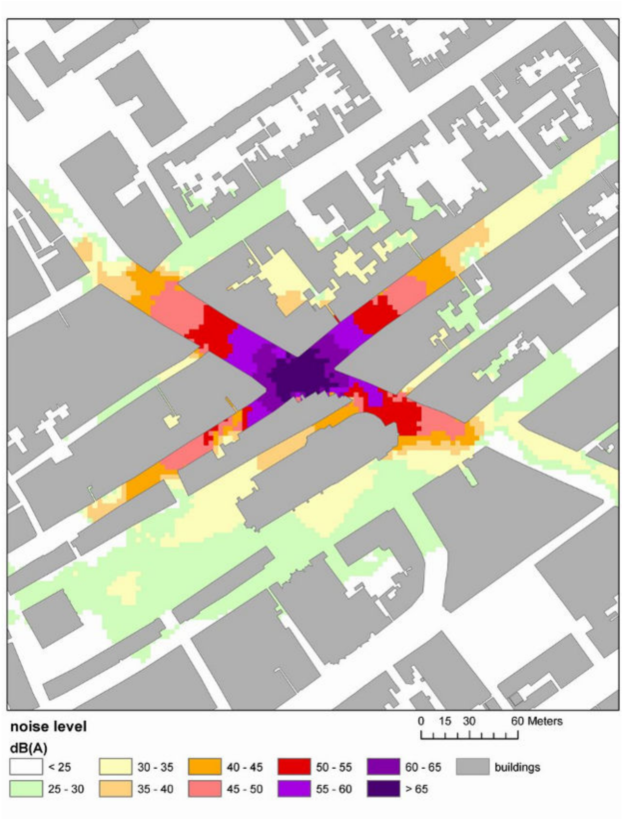

Fig 2 – Example of an inner city urban area and its corresponding noise map for a fictitious sound source.

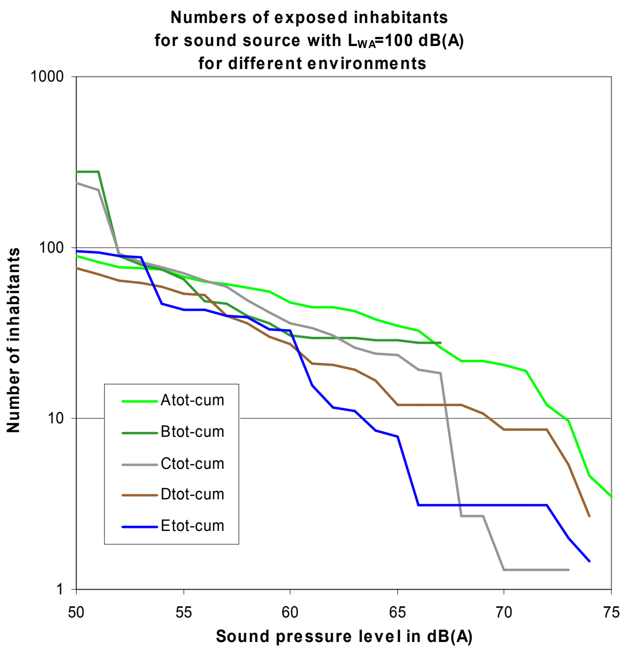

Fig 3 - Cumulative distribution of inhabitants indicating the number of people experiencing the indicated sound pressure level or more for a source of 100 dB(A) sound power for five typical urban situations.

For each equipment type the number of people affected was multiplied by the total amount of equipment in use within the EU. This gives the relative number of people, as a percentage of the total number of people for all situations considered, experiencing a certain year averaged equivalent sound level caused by the type of equipment in question

2.4 Definition of the Environmental Impact indicator

Combining the level and percentage according to energy summation, results in the relevant Environmental Impact indicator, the (relative) energy-averaged sound level that inhabitants in the EU25 experience on an average day of the year due to the considered equipment type:

$$EI_{\text{equip}} = 10\lg \sum_{i=1}^{10} \mathrm{N}_{\text{equip,situ}} \mathrm{D}_{\text{equip,situ},i} 10^{L_i/10}$$

where

- $\mathrm{N}_{\text{equip,situ}}$ number of equipment in use in specific situation;
- L_i sound level class i (5 dB classes);
- $\mathrm{D}_{\text{equip, situ,i}}$ distribution of inhabitants over sound level class i for each equipment and in each situation, normalized to the total number of inhabitants considered.

For each type of equipment one or two dominant environmental situations were selected. If more than one of those situations is applicable, the final indicator is the energy sum of the two partial indicators.

It was found that for the environments considered, a 3 dB reduction in sound power level resulted in on average in 35% less exposed people.

2.5 Availability of input data

All inputs data were are based on best estimates of the parameters from different sources. Equipment population numbers were estimated from various sources, such as national statistics, human population figures, sales figures per annum, probable ratios between equipment types and average life. No great accuracy is possible here, but is also not required; it suffices to know the order of magnitude. For example, there are tens of millions of lawnmowers, millions of power generators, hundreds of thousands of hydraulic hammers, tens of thousands of piling equipment and thousands of landfill compactors. Some data have been scaled up from the Netherlands using the human population ratio of 456 million (EU25) to 16 million (Netherlands), other data were based on industry sources.

It should be noted that all elements of the Environmental Impact indicator are in logarithmic form, such as number of people or number of equipment, reducing the sensitivity to small errors or changes in the inputs.

3 Results of EI computations

In figure 4 and 5 the overview is presented of the ranking of all types of equipment based on averaged guaranteed sound power level (fig. 4) and the Environmental Impact indicator (fig. 5). The range in dB for the various equipment types is expanded substantially by switching from the sound power level (range 33 dB(A)) to the Environmental Impact indicator (range 63 dB). This is caused by the effect of sound characteristics (10 dB range), total number of equipment in use (range 40 dB), usage time (range 30 dB)

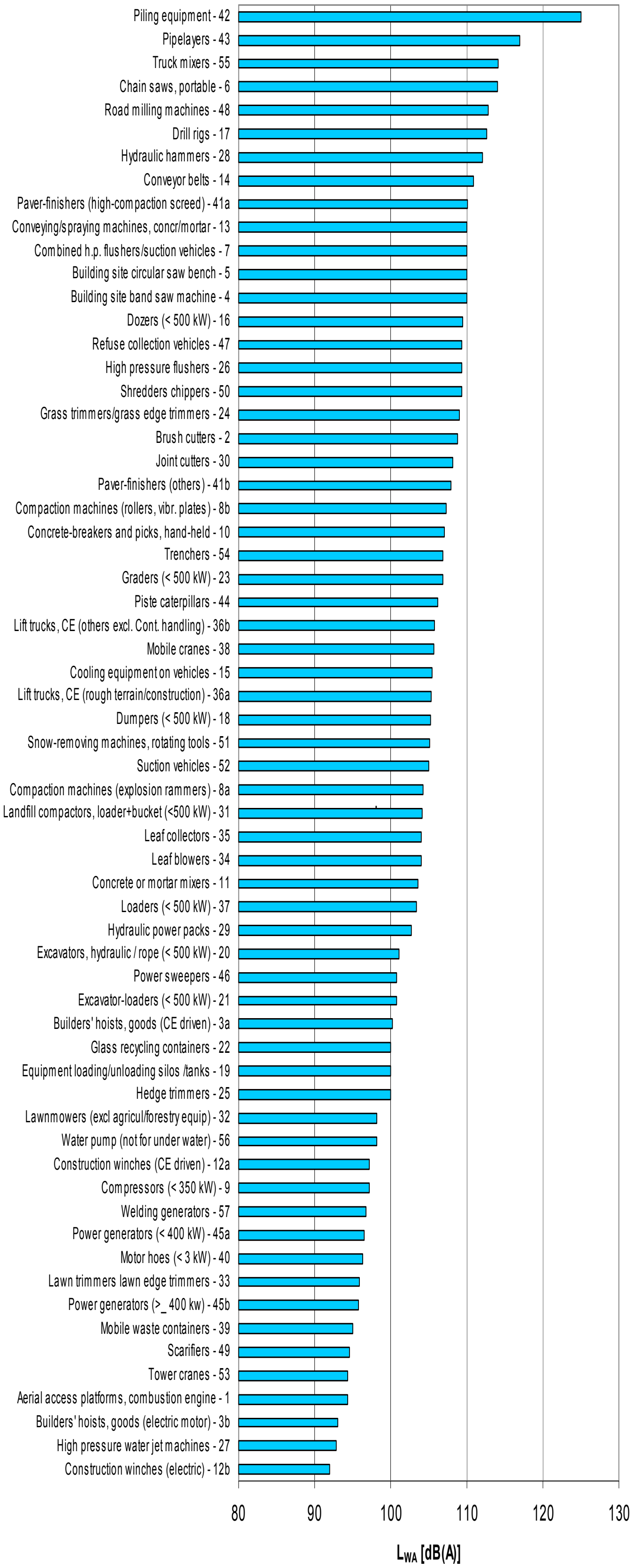

Fig 4 – Ranking of equipment according to the average guaranteed sound power level.

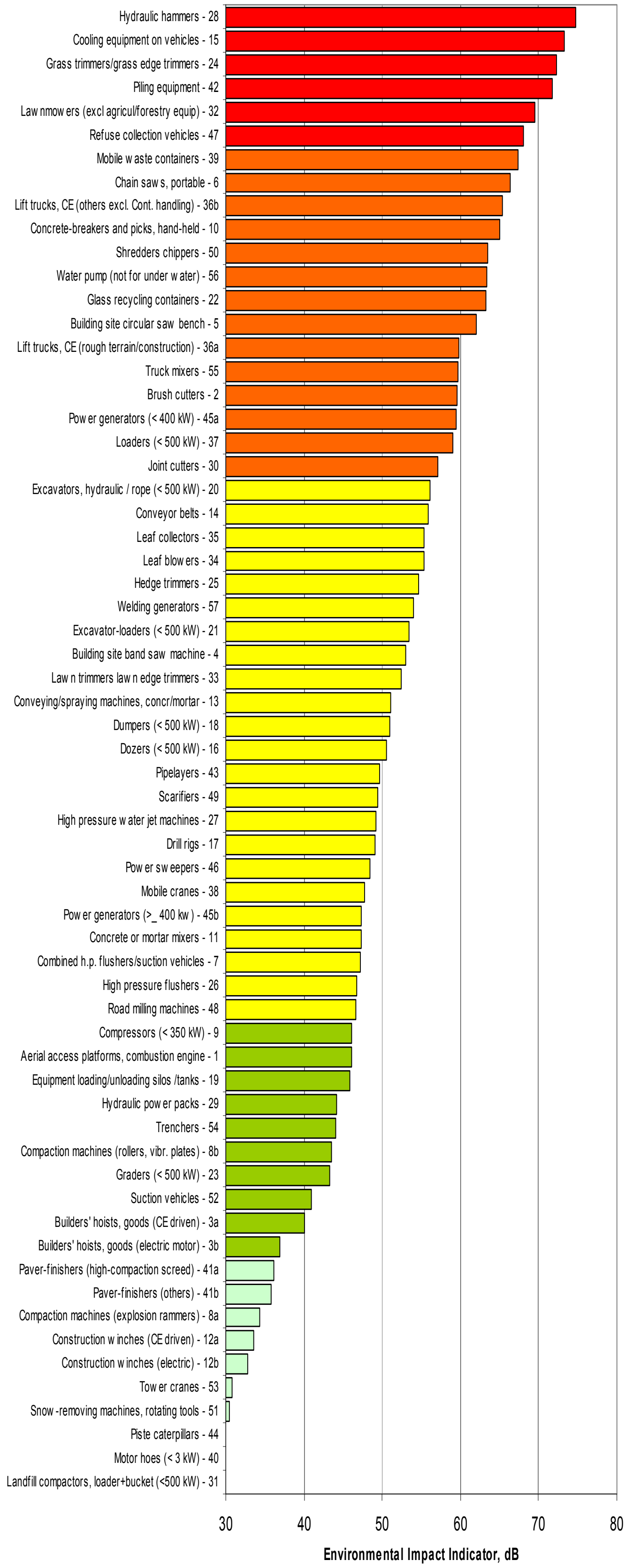

Fig 5 – Ranking of equipment according to the Environmental Impact indicator.

and the variation in environment (less than 10 dB).

A major result is that the ranking in sound power levels is completely different to the ranking in Environmental Impact, which is understandable when considering that some equipment types (e.g. lawnmowers) are far more numerous than others (e.g. snow removing machines).

For the average sound power levels as shown in figure 4, the top 10 include piling machines and other noisy construction equipment.

The top 10 equipment types in Environmental Impact are hydraulic hammers, cooling equipment on vehicles, grass trimmers, piling equipment, lawnmowers, refuse collection vehicles, mobile waste containers, chain saws, lift trucks and concrete breakers and picks. Most of these are either very numerous, have a long usage time and/or a high noise level combined with poor sound characteristics.

For the evaluation of the EU Directive the Environmental Impact ranking offered good opportunities to assess the environmental priority for stricter noise limit values for equipment types that are already subject to noise limits or for introduction of new limit values for equipment types that currently only need to be labeled. All equipment with an indicator value above 50 dB might be considered as qualified for stricter limits. All equipment below 37 dB might be considered of low importance for any effort in terms of noise limits. This includes construction winches, electric builder's hoists, paver finishers (all types), explosion rammers, snow-removing machines, tower cranes, piste caterpillars, landfill compactors and motor hoes.

These findings seemed consistent with the results of previously held environmental consultations.

A consequence of the chosen computation method was that the environmental impact in rural areas was rated relatively low, because the numbers of people affected have a strong influence on the outcome of the Environmental Indicator. If noise emission in rural areas were to be given a higher weighting some equipment types currently rated low might achieve a higher environmental impact.

4 Conclusions

By introducing a new Environmental Impact indicator, described in this paper, a generalised descriptor of the noise impact of different types of outdoor machinery became available that enabled the assessment of noise impact not only under local conditions, but also on a European scale. Although the computed Environmental Impact values still contain some uncertainty due to the input data, the ranking of equipment types based on these values seems to offer a logical and rational means of prioritising regulatory measures for the revision and enforcement of the EU Directive concerning outdoor equipment noise. As such this descriptor was used within the NOMEVAL evaluation study in combination with other considerations and evaluation results.

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References

[1] M. Dittrich, F. de Roo, E. Gerretsen, A. Burgess, H.J. Beckmann, G. Spellerberg, P. Cellard, A. Bowker, "Study on the experience in the implementation and administration of Directive 2000/14/EC relating to the noise emission in the environment by equipment for use outdoors - Final Report", TNO Report MON-RPT-033-DTS-2007-03482, 12 December 2007 (see www.ec.europa.eu/enterprise/mechan_equipment)

[2] M. Dittrich, F. de Roo, E. Gerretsen, A. Burgess, H.J. Beckmann, G. Spellerberg, P. Cellard, A. Bowker, "Evaluation of Directive 2000/14/EC on Outdoor Machinery Noise", *Proceedings Acoustics '08,* Paris, 2008.

[3] Directive 2000/14/EC of the European Parliament and the Council of 8 May 2000 on the approximation of the laws of the Member States to noise emission in the environment by equipment for use outdoors.

[4] ISO Acoustics 1996-1:2003 – "Description, measurement and assessment of environmental noise -- Part 1: Basic quantities and assessment procedures", ISO, Geneva, 2003.

[5] ISO Acoustics 1996-2:2007- "Description, measurement and assessment of environmental noise -- Part 2: Determination of environmental noise levels", ISO, Geneva, 2007.