Towards an complete Health Impact Assessment for Noise in Europe

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Summary
A health impact assessment based on the noise exposures distributions as reported under the Environmental Noise Directive (END) is presented for agglomerations. Shortcomings in the reporting data, an incomplete set, are overcome by gap-filling procedures. Focusing on the most dominant source (road traffic in agglomerations), the impact assessment indicates respectively 10 million and 4.3 million adults having severe annoyance and sleep disturbance. This is the double amount of the outcome of the previous health impact assessment based on the delivered data only (for agglomerations delivered before August 2013). Likewise, the results for hypertension double to 1 million cases each year, for hospital admissions to 47 thousand and for premature mortality due to coronary hearth diseases and stroke to 11 thousand cases each year. If the data are extrapolated to lower noise levels than those that are mandatory in the END and included in the health impact assessment, the estimation is that the results increase further with about 25% for severe annoyance and 70% for severe sleep disturbance. For hypertension, hospital admissions and premature mortality the increase is about 10%.

PACS no. 43.50.+y, 43.64.+r

1. Introduction

Noise exposure data reported for the European Noise Directive (END) can form a base for health impact assessment (HIA) in Europe. In 2014 in an assessment we estimated that about 9.1 million adults are highly annoyed and 3.7 million highly sleep disturbed. Furthermore, we estimated that noise contributes to about 910 thousand additional cases of hypertension in 2012, 43 thousand hospital admissions and 10 thousand cases of premature mortality each year, related to coronary heart disease and stroke. 90 Percent of this impact is related to road noise. These estimates were based on the END data for noise from roads, railways, aircrafts and industry, in and outside agglomerations, delivered before August 2013. The estimation was based on exposure-response relations, data on demographics and disease incidence of 33 European countries. [1][2].
Many uncertainties may influence these numbers, but the incompleteness of the dataset is a factor

that may lead to a structural underestimation of the health impact. Not all data have been delivered by all reporting countries. But even when data delivery will be complete, it will not cover the whole European population, because the END does not address exposure of the population in agglomerations < 100.000 inhabitants and other sources than the major sources. Furthermore the END only addresses exposure to levels higher than 55 dB L_{den} and 50 dB L_{night}, while health effects are also associated with lower levels.

To get a more complete picture of the noise exposure in Europe, we (i) impute noise exposure data that are not yet reported (gap-filling), and (ii) extrapolate to lower levels than the mandatory levels in the END. Subsequently, we demonstrate its influence on the estimated health impact. In this paper we present our findings on road noise in agglomerations. The preliminary assessment [1] has shown that the largest contribution to the health impacts can be attributed to traffic noise in agglomerations. The assessment on completed exposure data for more sources (major roads and railways, airports) will be reported by Houthuijs et al [3].

2. Applied methods

The END data-set was compiled based on earlier developed methods [4]. As many as possible agglomerations were included based on the data delivered before June 2014. For two third of the agglomerations recent data could be used. The method for imputation to 473 agglomerations with more than 100.000 inhabitants in the EEA33 is summarized in Table I.

Table I. Data source for road traffic noise within major agglomerations for 473 agglomerations.

Data-source	*# (percentage)*
Noise database 2012	318 (67%)
Noise database 2007	67 (14%)
Country specific	54 (11%)
Country specific	19 (4%)
European-wide	14 (3%)
No estimation for	1 (0.2%)

The next step was to create estimations for noise levels below 55 dB L_{den} (and 50 dB L_{night}) with a statistical model based on the available data for noise levels above 55 dB L_{den} (and 50 dB L_{night}). Instead of using a deterministic statistical model, we used two special cases of the 4 parameter Generalized Beta distribution of the second kind (GB2), the Singh-Maddala distribution and the Dagum distribution.

The GB2 demonstrated to work out well for the noise distribution within agglomerations. A program to fit a Singh-Maddala distribution to grouped data [5] was applied for each agglomeration, since we expected that the distribution in each agglomeration would be different. In case the program did not converge (24 of 473 agglomerations: 5%) a Dagum distribution was applied. This was successful for 4 agglomerations. We assumed that no exposure below 40 dB L_{den} will take place in an agglomeration. Therefore we used the fitted distribution between 40 and 55 dB to assess the number of residents per decibel in this range. For the 5 dB classes above 55 dB L_{den} we also used the fitted distribution within the 5 dB class to assess the number of residents per decibel. As a consequence the numbers of inhabitants per exposure category did not change in comparison with the reported numbers per agglomeration. For the remaining 20 agglomerations, we applied within each exposure category the average distribution based on the results of the 452 other agglomerations.

For L_{night} we repeated the same procedure to estimate the noise distribution between 25 and 50 dB. The application of a Singh-Maddala was successful in 465 cases; the remaining 5 agglomerations were fit with the Dagum distribution.

3. Noise exposure distribution

In Figure 1 the estimated distributions for L_{den} and for L_{night} are shown as fraction of the total population in the 473 agglomerations (176 million inhabitants). The statistical characteristics of the distributions are given in Table II. The estimated mean difference between L_{den} and L_{night} in the 473 agglomerations is 9 dB.

The percentage of the population exposed to road traffic noise exposure levels between 40 and 45 dB L_{den} is about 3%, between 45 and 50 dB 22% and between 50 and 55 dB 28%. 46% of the population lives at levels equal or above 55 dB L_{den}. For L_{night}, the percentage below 30 dB is about 1%, between 30 and 35 dB 4%, between 35 and 40 dB 14%, between 40 and 45 dB 25% and between 45 and 50 dB 25%. 32% of the population lives in areas with levels equal or above 50 dB L_{night}. Based on the delivered data, the gap filling and the statistical models we come to a distribution according to which the majority of the population in the agglomerations above 100,000 inhabitants live at noise levels below the mandatory levels that have to be assessed by the END.

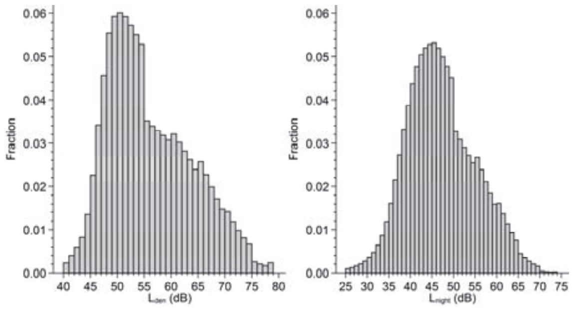

Figure 1. Estimated exposure distributions for residents to road noise inside agglomerations in EEA33, L_{den} and L_{night}.

Table II. Statistical distribution of L_{den} and L_{night} for road noise in 473 agglomerations (176 million inhabitants.

Mean and percentiles	L_{den}	L_{night}
mean	56.1	47.2
p5	45.5	35.5
p10	47.5	37.5
p25	49.5	41.5
p50	54.5	46.5
p75	61.5	52.5
p90	67.5	58.5
p95	70.5	61.5
p99	74.5	66.5

4. Consequences for health impact assessment

In Table III the outcomes of the health impact assessment are reported in absolute numbers.
The preliminary assessment [1, 2] was based on exposure data for only 42 million residents (L_{den}) and for 30 million residents (L_{night}). The imputed set, (gap-filling of data that were supposed to be delivered) includes nearly the double amount of residents (82 and 58 million residents for L_{den} and L_{night}, respectively). This doubling is also noted in the size of the health impact that is shown in the third column of table III. For example, severe sleep disturbance increases from 2.2 to 4.3 million adults.
Finally, if we extend the health impact assessment and include all 177 million residents in the agglomerations, so including also noise exposure levels below 55 dB L_{den} and 50 dB L_{night}, the size of the annoyance increases further from 21.5 to 29.5 million. All results are visible in the right column of table III, where we see the largest increase for sleep disturbance from 9.2 to 17.2 million adults.

Table III Results of the health impact assessment for road traffic noise in agglomerations (177 million residents).

Health endpoint	*Noise in Europe 2014 (EEA, 2014)*	*Gap filled data-set with 473 agglomerations*	
		Exposure >55 dB L_{den} & >50 dB L_{night}	*Imputed full distribution & extended exposure-response*
Annoyance (*million)	10.9	21.5	29.5
Severe annoyance (*million)	5.0	10.0	12.5
Sleep disturbance (*million)	4.7	9.2	17.2
Severe sleep disturbance (*million)	2.2	4.3	7.3
Hypertension (*million)	0.49	1.0	1.1
Hospital admissions (*thousand)	25.1	47.4	52.6
Premature mortality (*thousand)	5.7	11.0	12.2

The results above are illustrated by Figure 2 in which the results for highly annoyed, highly sleep disturbed and premature mortality are shown per decibel as fraction of the total impact.

From Figure 2 it becomes clear that L_{den} levels between 60 and 70 dB contribute the most to the total impact of road traffic noise in agglomerations, but that a substantial contribution can be expected from lower levels, in particular for severe annoyance. For highly sleep disturbed, the largest contribution can be expected from levels between 45 and 60 dB L_{night}. Considering premature mortality, the contribution from levels below 55 dB in large agglomerations is small.

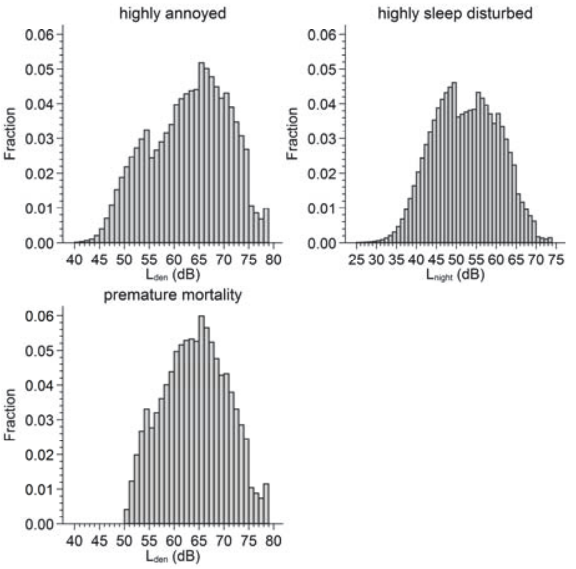

Figure 2 Health impact per decibel for highly annoyed, highly sleep disturbed and premature mortality, expressed as fraction of the total impact of road traffic within agglomerations.

5. Discussion

In developing a method to extrapolate data to levels below 55 dB L_{den} and 50 dB L_{night} we used two leading principles, namely that the delivered data is correct and that within agglomerations, people are exposed to minimum levels of 40 dB L_{den} and 25 dB L_{night}. However, the delivered data contain uncertainties, depending on many factors that are unknown. We know that the exclusion of minor roads in modelling is a factor that influences the results above 55 dB L_{den} per agglomeration, but we did not have the background information to analyze this on a structural base.

Often also for severe annoyance and for (severe) sleep disturbance a 'threshold' value for the exposure-response functions is applied. For severe annoyance this is not necessary, since the original functions describe that also below levels of 42 dB L_{den} a certain risk is present (see [6]). For (severe) sleep disturbance it was stated that the exposure-response relations are valid in the range of 40 to 65 dB L_{night}, given the exposure range in the underlying studies [7]. Because at 40 dB still a substantial percentage of noise induced (severe) sleep disturbance is reported, it makes sense to extrapolate the exposure response function to lower levels. This has been done in the results that have been presented in this paper

6. Conclusion

In conclusion, we consider the assessment based on the gap filled data-set of 473 agglomerations with more than 100.000 inhabitants, with 82.0 million residents living equal of above 55 L_{den} and 57.3 million living equal or above 50 dB L_{night} as the expected 100% result of the END noise mapping. In table IV it can be seen that in our first assessment, based on the delivered data in august 2013 we reported about 50% of this expected result.

Table IV Results of the health impact assessment for road traffic noise in agglomerations (177 million residents) in percentages of the results of the gap-filled dataset.

Health endpoint	*Noise in Europe 2014 (EEA, 2014)*	*Gap filled data-set with 473 agglomerations*	
		Exposure >55 dB L_{den} & >50 dB L_{night}	*Imputed full distribution & extended exposure-response*
Annoyance	51%	100%	137%
Severe annoyance	50%	100%	125%
Sleep disturbance	51%	100%	187%
Severe sleep disturbance	51%	100%	170%
Hypertension	49%	100%	110%
Hospital admissions	53%	100%	111%
Premature mortality	51%	100%	137%

If we also include noise exposure levels below 55 dB L_{den} and 50 dB L_{night}, we see a further increase. For the cardiovascular health impact this is limited to about 10% extra. For severe annoyance we calculated an increase of 25% and for annoyance 37%. The influence on sleep disturbance is the highest, showing an increase of 87% and 70% for (severe) sleep disturbance. The sharp increase in (severe) sleep disturbance is related to the relative small part of the population (32%) that is in the catchment area for the noise assessment in the framework of the END. The relatively small increase in the size of the noise induced cardiovascular endpoints can by explained by the underlying assumption that there is no additional risk for these health endpoints at levels below 50 dB L_{den}.

Acknowledgement

This study has been carried out by order and for the account of European Environment Agency, within the framework of European Topic Centre for Air Pollution and Climate Change Mitigation

References

[1] D.J.M.Houthuijs, A.J. van Beek, W.J.R. Swart, E.E.M.M. van Kempen: Health implication of road, railway and aircraft noise in the European Union, Provisional results based on the 2nd round of noise mapping. RIVM Report 2014-0130, RIVM, Bilthoven, 2014.

[2] European Environment Agency: Noise in Europe 2014. EEA report 10/2014. European Environment Agency, Copenhagen, 2014.

[3] D.J.M.Houthuijs, A.J. van Beek, W.J.R. Swart, E.E.M.M. van Kempen, F.A.A.M. de Leeuw: Health Impact Assessment for Noise in Europe, Expected consequences of the limitations of the available noise exposure data, Technical Report ETC ACM, draft

[4] Extrium: Technical note to the European Environment Agency on forecasting ENDRM DF4_8 data to 2020, 2030 and 2050, 29 November 2013, (http://forum.eionet.europa.eu/nrc-noise/library/noise-report-2014)

[5] S.P. Jenkins: Fitting Singh-Maddala and Dagum distributions by maximum likelihood. StataTechnical Bulletin STB 48 (1999) 19–25.

[6] H.M.E. Miedema, C.G.M. Oudshoorn: Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals. Environ Health Perspect 109 (2001) 409–416.

[7] H.M.E Miedema, H. Vos: Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies. Behavioral Sleep Medicine 5 (2007) 1-20.