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Case study of an environmental noise and health assessment in the City of Dusseldorf, Germany

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ABSTRACT

In their recent Environmental Noise Guidelines (ENG) the World Health Organization (WHO) identified several critical health outcomes of environmental noise, among them are cardiovascular diseases, annoyance, effects on sleep, cognitive impairment, and hearing impairment/ tinnitus. Aiming at protecting the population from adverse noise effects, the Environmental Noise Directive 2002/49/EC (END) is the main instrument guiding the noise mapping and the development of noise action plans in EU Member States. END Annex III describes methods of the assessment of health impacts (HIA) of noise in terms of the number of highly annoyed and sleep disturbed persons in a given area. A new study commissioned by the European Commission describes a HIA methodology for environmental noise, which considers the critical health outcomes as identified in the WHO ENG. In summary, two methods are described: the assessment of number of people affected by different health outcomes and the environmental burden due to environmental noise in terms of the calculation of disability-adjusted live years (DALY). We present a case study where both HIA methods were applied to the City of Dusseldorf, Germany, in order to describe the status quo of the health impact as well as the health impact of simulated transportation noise interventions.

Keywords: Environmental noise, health impact assessment

1. INTRODUCTION

The EU Environmental Noise Directive 2002/49/EC (END; 1) is the main instrument guiding the noise mapping and the development of noise action plans in EU Member States, aiming at protecting the population from adverse noise effects.

As stated in END Annex III: 'Dose-effect relations should be used to assess the effect of noise on populations.' According to the current version, the exposure-response relationship should concern the relation between (1) annoyance and L_{den} and (2) between sleep disturbance and L_{night}, for road, rail and air traffic noise as well as for industrial noise.

The European Commission aims to revise Appendix III based on latest scientific evidence of the impact of environmental noise on health as provided by systematic reviews. These systematic reviews were carried out within the frame of the Environmental Noise Guidelines (ENG) for the European Region and were published by the World Health Organization (WHO) in 2018 (2). In the WHO ENG several outcomes of environmental noise are identified. Health outcomes defined as critical are, annoyance, sleep disturbance, cardiovascular diseases, cognitive impairment, and hearing impairment/tinnitus. Whereas the latter mainly refers to leisure noise, the other critical outcomes have

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been mainly studied as impacts of transportation noise, i.e. aircraft, railway, and road traffic noise.

The European Commission has commissioned a new study to develop a health impact assessment (HIA) methodology for environmental noise which considers the critical health outcomes as identified in the WHO ENG (3). The methodology is described in another contribution by Van Kamp et al. (4).

This contribution refers to the application of the HIA methodology to the City of Dusseldorf, Germany, examining two key questions:

(1) What is the status quo of the health impact of environmental noise (in the following focused on transportation noise) in Dusseldorf?
(2) What are the impacts of selected noise mitigation actions on health?

To address these questions, the following indices were used and calculated for transportation noise (road, railway, and aircraft traffic noise): 1) number of people affected by different health outcomes (NafP) and 2) the environmental burden due to environmental noise (disability-adjusted live years, DALY) (Step 1, see section 2.3).

Concerning the former, the number of highly annoyed people, of highly sleep disturbed people as well as the number of people with a coronary heart disease (CHD) per year and number of deaths due to CHD – both attributable to noise – were calculated for the three transportation noise sources. For aircraft noise, the number of children with reading impairment was assessed as well.

Except for children's reading impairment, the above listed health outcomes were also used for the DALYs. In addition, DALY calculations excluding high noise annoyance and high sleep disturbance were compared to calculations including these two variables.

2. PROCEDURE, METHODS

2.1 Study area

The selected study area, Dusseldorf, Germany, has a total of 635,704 inhabitants, of which 537,631 are adults, i.e. are 18 years and older (85%). For this area, noise calculations have been made within the frame of the 3rd round of the noise mapping according to the EU directive for environmental noise (1). For one city district, Dusseldorf-Bilk, the Environment Agency of Dusseldorf (EAD) additionally calculated the impact of three simulated source-specific noise abatement actions on changes in the number of exposed residents. These actions are:

1. Road traffic noise: Noise reducing road surfaces
2. Railway noise: Green tech rail profiles
3. Road traffic noise: Speed Limit 30 km/h (as compared to 50 km/h)

2.2 Data

The EAD provided population-exposure data for road, railway and aircraft traffic noise by linking noise maps to residents' addresses. L_{den} and L_{night} were used as acoustical measures. Both were divided into 1 dB classes. Table 1 shows the dB ranges per noise source. It has to be noted that for aircraft noise, the EAD could not provide noise exposure data below 45 dB, as the aircraft noise exposure estimations are done by a different authority.

Table 1 – Ranges of acoustical measurements

Noise source	L_{den}	L_{night}
Road traffic	<40 to 78 dB	<40 to 69 dB
Railway traffic	<40 to 90 dB	<40 to 81 dB
Aircraft traffic	45 to 75 dB	45 to 66 dB

Demographic data such as age was derived from an official report (5) by the City of Dusseldorf (2016). Data regarding the mortality rate of CHD was taken from the WHO Mortality database for Germany (2015). Incidences for CHD were operationalized using hospital discharges. Here, data was available from the European Hospital Morbidity Database of the WHO (2014). DALYs are calculated by adding the years lived with a disease (YLD) and the years of life lost due to a disease (YLL). The data used to calculate DALYs were extracted from the WHO Burden of Disease project (2016) (6). For this HIA example, it is assumed that the data are valid for Dusseldorf.

2.3 Methods

The HIA assessments (NafP, DALYs) are carried out in five steps:

Step 1: Choice of health outcomes (see introduction)

Step 2: Exposure assessment

Step 3: Choice of exposure-response functions

Step 4: Estimation of the NafP by transportation noise on the basis of step 1 to 3 and additional social-spatial population data (number of residents in total, by age and gender)

Step 5: Estimation of DALYs due to transportation noise on the basis of step 1 to 4 and additional data on health outcome-specific YLD and YLL.

3. RESULTS

3.1 HIA assessment process

In order to assess the status quo of the noise situation in Dusseldorf, noise data divided in 1-dB classes ranging from 40 to 75 dB for L_{den} and L_{night} was used for road and railway traffic as well as for industry and harbor noise. For aircraft noise, a range from 45 dB to 75 dB was used for L_{den}.

To calculate the change in noise exposure, both of the two simulated noise interventions concerning road traffic noise (noise reducing road surfaces and speed limit 30km/h) were used. The calculated change in noise exposure regarding railway noise was assessed with one simulated intervention (green tech rail profiles). The EAD then estimated the change in numbers of people exposed to traffic noise for 1-dB classes (L_{den} and L_{night}) (step 2).

Figures 1 and 2 show the distributions of people exposed to road and railway noise before and after the implementation of the simulated noise mitigation actions in Dusseldorf-Bilk. It seems that the proposed interventions do not strongly affect the percentage of noise exposed residents.

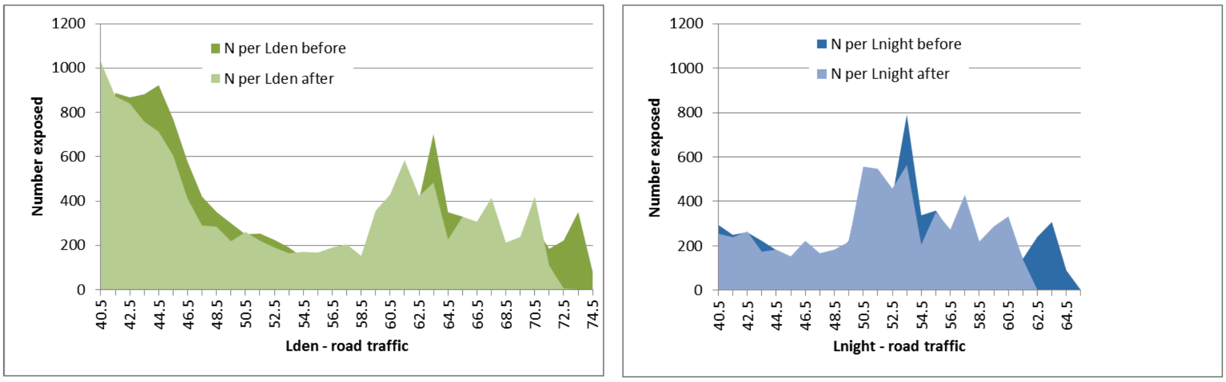

Figure 1 – Road traffic: Noise reducing road surfaces and speed limit reduction

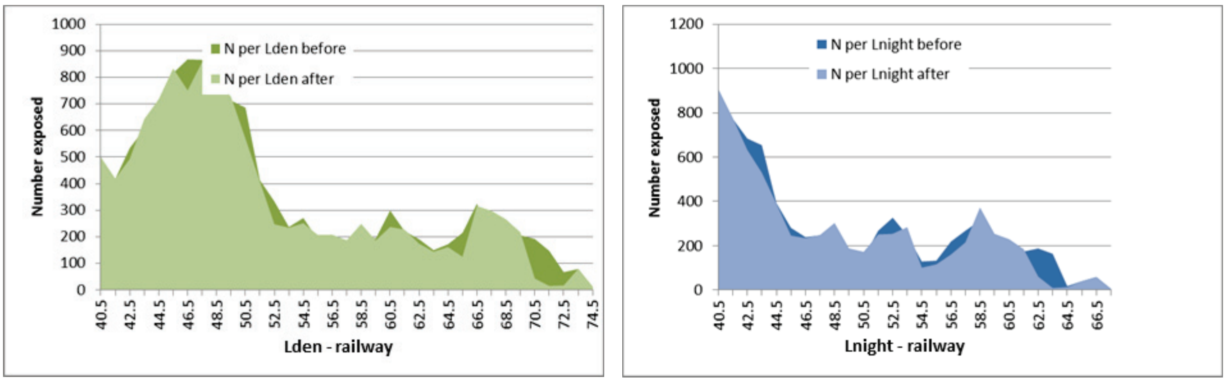

Figure 2 – Railway: Green tech rail profiles

3.2 HIA method 1 - NafP

For the HIA the following exposure functions are used (Step 3): For the percentage of highly annoyed people (%HA), the generalized exposure response function (ERF) from the WHO review for environmental noise annoyance (7) was used. The number of highly sleep disturbed people (%HSD) was assessed using the ERFs of the WHO review for the impact of environmental noise on sleep (8).

The ERF used to estimate the number of children with reading impairment due to aircraft noise can be found in (3).

In order to calculate the incidence of CHD and the number of deaths related to CHD, both attributable to noise, the so-called PAF (noise source-specific population attributed fraction) was used (3, 4). Both PAFs were multiplied with the corresponding variable (i.e. hospital discharge rate and the mortality rate for CHD) and the total number of residents in Dusseldorf. In both cases, this was done for females and males separately

Table 2 shows the number of adult people annoyed and sleep disturbed by transportation noise and the number of children with reading comprehension impaired by aircraft noise. Table 3 gives an example of CHD incidence and mortality attributable to transportation noise for females and males, respectively (Step 4).

Table 2 – Estimated number of highly noise annoyed and sleep disturbed adult people and children with reading impairment by aircraft noise in Dusseldorf

Health end point	Noise source	Number	Percent
Highly annoyed (adults)	Road	63,558	11.82 %
	Rail	47,089	8.76 %
	Air	35,542	6.61 %
Highly sleep disturbed (adults)	Road	12,344	2.30 %
	Rail	16,551	3.08 %
	Air	569	0.11 %
Children with additional reading impairment due to aircraft noise	Air	7,328	10.07 %
N_{adults}		537,631	100.00 %
$N_{children\ (7\text{-}17\ years\ old)}$		72,742	100.00 %

Table 3 – Estimated number of people with CHD attributable to transportation noise in Dusseldorf

Health end point	Noise source	Total estimated hospital discharges/ death in Dusseldorf attributable to noise		
		Male	Female	Sum
CHD incidence	Road	56	28	84
	Rail	33	16	50
	Air	2	1	3
CHD mortality	Road	154	135	289
	Rail	91	80	171
	Air	5	5	10

3.3 HIA method 2 - DALY

Additionally, the DALYs were calculated for CHD incidence and mortality for each noise source (Step 5). For comparison, the DALYs were also calculated including the variables high annoyance and high sleep disturbance. A disability weight of .01 was used for %HA and a disability weight of .0175 for %HSD. The number of DALYs regarding CHD due to noise is 621 (DALY I). When high sleep disturbance and high annoyance are taken into account as well, this number increases to 2,760 (DALY II). Table 4 gives an overview of the results.

Table 4 – DALYs for the current noise situation in Dusseldorf

Health end point	Noise source	Average estimated prevalence	PAF	Disability weight	Total YLD	Total YLL	Average DALYs
High annoyance	Road	63558		0.01	636	0	636
	Rail	47089		0.01	471	0	471
	Air	35542		0.01	355	0	355
High sleep disturbance	Road	12344		0.0175	284	0	284
	Rail	16551		0.0175	381	0	381
	Air	569		0.0175	13	0	13
CHD incidence	Road		0.0146		982		14
	Rail		0.0087		982		9
	Air		0.0005		982		1
CHD mortality	Road		0.0182			20148	367
	Rail		0.0108			20148	218
	Air		0.0006			20148	13
DALY I							621
DALY II							2760

Note. DALY = Disability-Adjusted Life Years, CHD = coronary heart diseases, PAF = average population attributive fraction, YLD= Years of life lost due to disability, YLL= Years of Life lost due to premature death. DALY I = DALYs calculation excludes DALYs due to noise annoyance and sleep disturbance, following GBD. DALY II = DALYs calculation includes DALYs due to noise annoyance and sleep disturbance.

3.4 HIA regarding the impact of noise mitigation actions

The second aim was to examine the effects of simulated interventions regarding road and railway noise on NafPs and DALYs. Figure 3 depicts the study area Dusseldorf-Bilk and the locations of the three interventions.

Table 5 presents the results regarding the health impact of the three simulated interventions (before and after). As aircraft traffic noise is not affected by these interventions, it is not considered.

The two simulated interventions concerning road traffic noise would reduce the DALYs by 9.8% (DALY I) and by 8.4% when high noise annoyance and high sleep disturbance are included (DALY II). The number of highly annoyed people would decrease by 106 people (-0.3%) and minus 26 people would be highly sleep disturbed (-0.2%). Regarding CHD mortality, the number of deaths would be reduced by one.

The simulated intervention affecting railway noise yields similar results. DALY I was found to decrease by 9.1%.Adding annoyance and sleep disturbance to the calculation results in a decrease of 2.02 DALYs (7.8%). The number of CHD incidence and mortality would not be affected by the intervention.

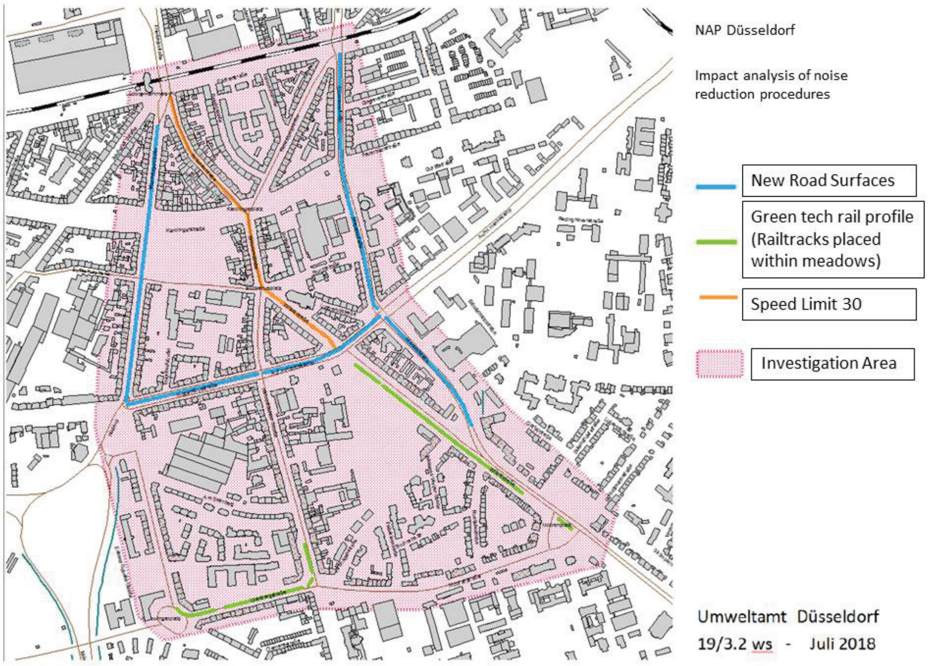

Figure 3 - Study area and delineation of the three noise reduction procedures

Table 5 – Overview of NafP (HIA method 1) and DALYs (HIA method 2) before and after interventions on road traffic noise

Health end point	Noise source	Average NafP (before*)	Average NafP (after*)	Difference in NafP	Average DALYs due to noise (before)	Average DALYs due to noise (after)	Average difference in DALYs
		Measure: Noise reducing road surfaces and speed limit 30 km/h					
High annoyance	Road	1490.2 (11.4%)	1384.6 (10.6%)	-105.6 (-0.8%)	14.90	13.85	-1.06 (-7.1%)
High sleep disturbance	Road	289.4 (2.2%)	263.1 (2.0%)	-26.3 (-0.2%)	6.66	6.05	-0.60 (-9.0%)
CHD Incidence	Road	2,2	2.0	-0.2	0.38	0.34	-0.04 (-10.5%)
CHD mortality	Road	7.7	6.9	-0.7	9.76	8.81	-0.95 (-9.7%)
DALY I		--	--	--	10.15	9.16	-0.99 (-9.8%)
DALY II		--	--	--	31.70	29.06	-2.65 (-8.4%)

Table 6 – Overview of NafP (HIA method 1) and DALYs (HIA method 2) before and after an intervention on tram (railway) noise

Health end point	Noise source	Average NafP (before*)	Average NafP (after*)	Difference in NafP	Average DALYs due to noise (before)	Average DALYs due to noise (after)	Average difference in DALYs
				Measure: Green tech rail profiles			
High annoyance	Tram (rail)	1056.8 (8.1%)	991.9 (7.6%)	-64.9 (-0.5%)	10.57	9.92	-0.65 (-6.2%)
High sleep disturbance	Tram (rail)	394.7 (3.0%)	360.0 (2.8%)	-34.7 (-0.2%)	9.08	8.28	-0.80 (-8.8%)
CHD incidence	Tram (rail)	1.4	1.3	-0.1	0.24	0.21	-0.02 (-8.3%)
CHD mortality	Tram (rail)	4.8	4.3	-0.4	6.05	5.50	-0.55 (-9.1%)
DALY I		--	--	--	6.29	5.72	-0.57 (-9.1%)
DALY II		--	--	--	25.93	23.92	-2.02 (-7.8%)

Note. DALY = Disability-Adjusted Life Years, CHD = coronary heart diseases, PAF = average population attributive fraction, YLD= Years of life lost due to disability, YLL= Years of Life lost due to premature death. DALY I = DALYs calculation excludes DALYs due to noise annoyance and sleep disturbance. DALY II = DALYs calculation includes DALYs due to noise annoyance and sleep disturbance. *Before and after the interventions.

4. Conclusions

The described analyses show that different (additional) data sources, on which basis NafP and DALYs are calculated, are needed. For example, specifically for DALYs, data was only available nation-wide, but not at a city level (Dusseldorf). Due to the fact that in Germany different authorities are responsible for noise mapping, depending on the noise source, and for gathering epidemiological as well as socio-spatial data these data may differ in their level of detail. The application of national epidemiological data to a local level required assumptions to be made on the validity of this application and may produce uncertainty in the assessments.

As there are no regional ERFs available for annoyance and sleep disturbance in Germany, generalized ERFs were used in these analyses. This does not pose a problem when evaluating the impact of interventions. However, since characteristics of the local population are not taken into account in ERFs, estimating the number of highly annoyed or highly sleep disturbed people could be problematic in terms of the validity of the assessments.

In addition, certain health outcomes take many years to develop and, therefore, short-term noise changes, as assessed in this HIA, may not yield any effects.

Both HIA methods, but in particular the DALY calculations, are complex and need epidemiological exercise.

Deciding on a noise intervention, i.e. targeting either road or railway noise, is a question of the HIA method used. Using NafPs, the road traffic noise interventions would be more effective, as it results in the highest decrease in affected (highly annoyed) people. On the other hand, the railway intervention would reduce the percentage of highly sleep disturbed people and, thus, should be chosen when aiming at improvements during the night.

So far, the DALYs I only include CHD and are not recommended for evaluating noise action plans as it provides little information for any preferences. In the near future, more robust ERFs should be available for other effects (e.g. stroke, diabetes), as more studies on the impacts of environmental noise are being published. These effects could, then, be included in the DALYs I or II.

Overall, DALY II as well as NafP seem more appropriate to describe the status quo of the effects of environmental noise on health at a (larger) city level. When it comes to evaluating and comparing different noise scenarios at a noise action plan level, DALY (either I or II) should be accompanied by another HIA method.

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