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Study on methodology to perform an environmental noise and health assessment - a guidance document for local authorities in Europe

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ABSTRACT

The Environmental Noise Directive (END) is for local authorities the most important instrument to determine the levels of noise pollution. The Directive aims at the evaluation of effect of measures and can make the effects of alternative measures visible. The Directive stimulates the Member States to take action to reduce the aversive effects of environmental noise. In preparation of the update of Annex III of the Directive, RIVM in collaboration with international partners, has prepared a guidance document taking the new Environmental Noise Guidelines for the European Region (WHO) as a point of departure. Not only annoyance and sleep disturbance are addressed as health effects, but also cardiovascular effects and cognitive impact on children (comprehensive reading impairment). The guidance document was prepared on request of the EU commission. This paper summarizes the steps of a health impact assessment and explains the accompanying decisions and conditions. The actual calculation methods are further explained taking sleep disturbance as an example and are restricted to the number of people that experiences adverse effects of noise.

1. INTRODUCTION

Annex III of the Environmental Noise Directive 2002/49/EC (END) will describe a method for calculating the health impacts of exposure to environmental noise levels from different sources. Currently, Annex III is under revision, following the latest scientific evidence of the health effects of noise reviewed for an update of the formerly named Community Noise Guidelines of WHO[1] now referred to as the Environmental Noise Guidelines for the European Region.

In 2010, the European Environmental Agency (EEA) published its "Good practice guide on noise exposure and health effects (GPG)"[2] which intended to assist policy makers, competent authorities and any other interested party in understanding and fulfilling the requirements of the European Noise Directive. The main aim of the GPG was to provide end users with practical and validated tools to calculate the health impacts of noise in strategic noise studies such as the Noise Action Plans (NAPs) of the Directive. However it does not provide guidance on how health and well-being effects can be estimated, and used to justify or establish priorities within the NAPs.

The main aim of this project was to develop a guidance tool that can be used to assess and evaluate the (cumulative) health effects at the population level due to environmental noise exposure to complement the noise mapping and to inform on the health benefits of the actions foreseen in the noise action plans performed according to articles 1, 7 and 8 of the Environmental Noise Directive.

Specific objectives of the project were:

1. To select and evaluate environmental health indicators suitable to apply in the END context;
2. To give insight in what data is needed to calculate the environmental health indicators and to determine the scale level at which they can be applied;
3. To give insight in when and how the different indicators can be used in a health impact assessment for environmental noise;
4. To develop a methodology and guidance tool at least at city level;
5. To apply the selected indicators in a case study.

This project was based on the following assumptions:

- The WHO reviews prepared in the framework of the new Environmental Noise Guidelines[1] are taken as a point of departure; http://www.mdpi.com/journal/ijerph/special_issues/WHO_reviews.
- Scientific evidence on noise and health published after the timeframe of the reviews is also accounted for.
- The described methodology considers noise sources separately and integrates health effects where relevant.
- The main focus is on adults (18 years and older), but when data is available for specific groups, like children, this can be used as input for the methodology.
- To apply the disability adjusted life years indicator (DALY) and one or more additional environmental health indicators in a case study.
- To preferably express the burden of disease in a single value, so it has added value to the noise maps.
- The methodology to be at least valid at city level (≥100.000 inhabitants).

2. STUDY DESIGN AND METHODOLOGY

2.1 Tasks

Practically the aims and objectives of the project as described above were translated in the following tasks and deliverables:

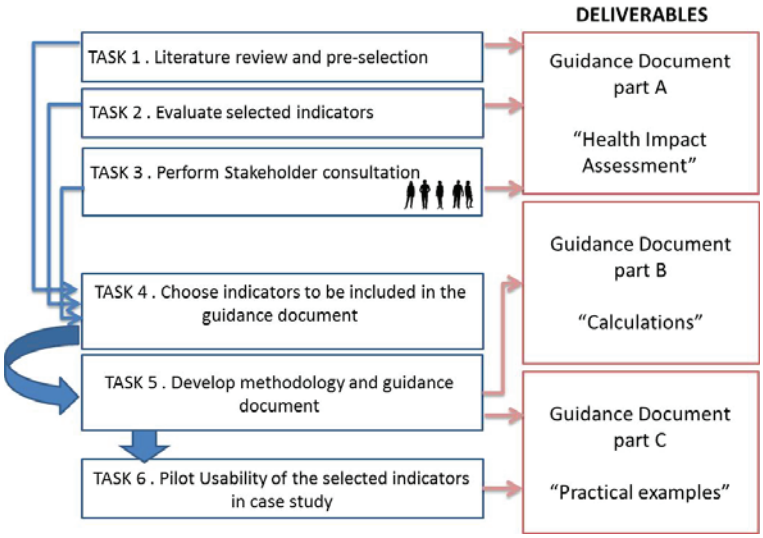

Figure 1.1: Overview of tasks and deliverables

2.2 Readers Guide

As can be seen in Figure 1.1 a distinction was made between the Guidance Document parts A, B and C. Part A describes the key steps in a Health Impact Assessment (HIA) for noise effects on health, theoretical backgrounds and the process of indicator selection and the main decisions to be taken in the

HIA process; Guidance Document part B provides guidance for the actual calculation. Part A and B will be summarized below, while Part C, which gives two practical examples of a HIA in Dusseldorf will be described elsewhere.

3. GUIDANCE DOCUMENT PART A: Health Impact Assessment

3.1 Steps in the HIA process: a model

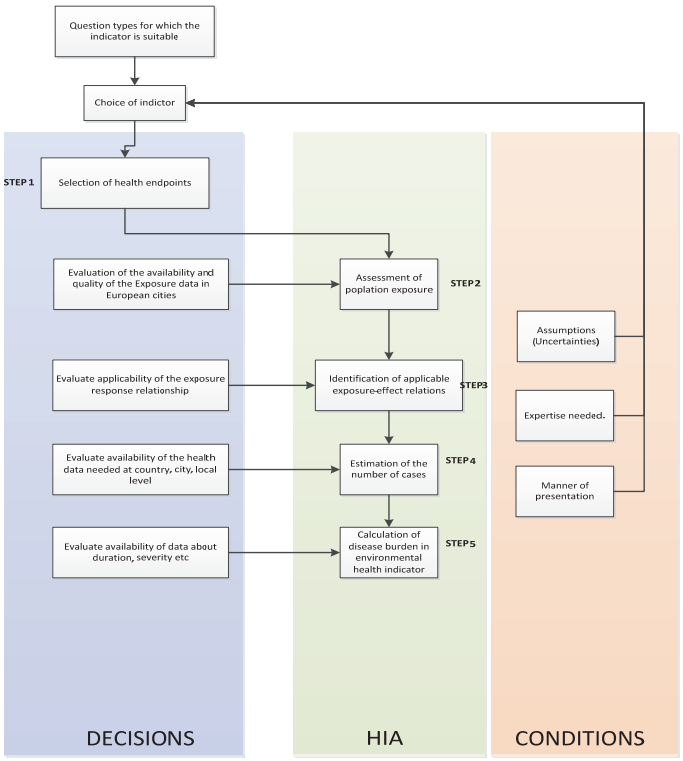

Figure 3.1: Steps in evaluation process at different layers

Figure 3.1 describes the different decisions to be made preceding a HIA as well as the key steps of an impact assessment These steps are accompanied by a set of decisions, on e.g. the quality of exposure data, availability of the health data and applicability of the ERFs (at a given scale level (see left column) and a set of conditions, such as the underlying assumptions, the expertise needed to perform the HIA and the preferred way and scale of presenting the results (right column). After these decisions have been made and the conditions as described above are met and the actual HIA can take place.

3.1.1 Policy Questions

Starting point of a HIA are the policy questions to be addressed. These questions strongly determine whether a HIA is a suitable tool to answer the questions and whether a given environmental health indicator is suitable for the task at hand. These questions of course do not only pertain to environmental noise, but often are part of larger questions about the impacts of infrastructural plans or choices for actions at specific locations. In the context of END we focus on the noise related questions. Roughly these questions can be subdivided in the following main policy questions:

1. Mapping the current status in terms of exposure and their health effect at different scale levels, and for different social groups.
2. Choice of and prioritization of location of the actions.
3. Choice of mitigating actions with highest impact.
4. Evaluation of noise action plans (NAPS). (Evaluation of the health impact of different actions; evaluation of health impact of deviations from limit values; efficiency analysis of a set of interventions .

Since most of the ERFs for the health outcomes for environmental noise are non-linear it is essential that results from different action plans are compared based on the magnitude of the resultant change in the health effects, not just on the change in noise levels that result from the action plan. A recent systematic review of transport noise interventions[3] and their impact on health noted that, in decades of environmental noise interventions (or noise management, or noise control), only a very small number of studies estimated the effect of the interventions in terms of health outcomes rather than in noise level changes. The review also provided an intervention framework showing system components of the path between environmental noise and human health and where different types of noise intervention potentially act along that path. To lower the level at the receiver side interventions on each part of the path can be made. At the source side, emission levels can be changed (road surface change or traffic flow change) or time restrictions on use of vehicles can be placed (type A intervention). In the transmission path, barriers can be placed to change the path between source and receiver or the building envelope can be insulated (type B intervention). In addition, the location of dwellings in relation to infrastructure can be changed to make the transmission path from source to receiver longer (type C intervention). These intervention types are summarized in figure 3.2.[3]

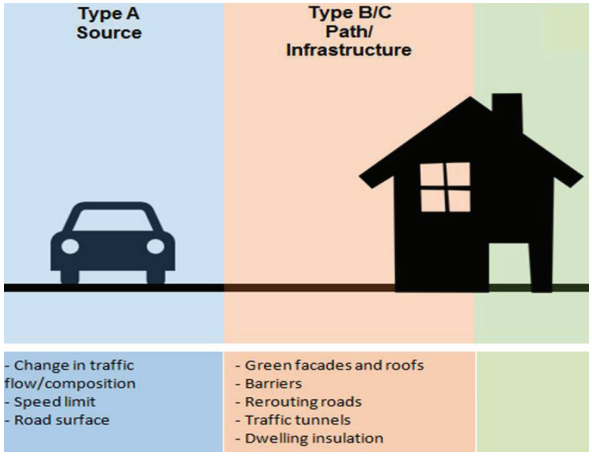

Figure 3.2: Type of Interventions

3.2 Choice of indicators

The policy questions primarily determine the suitability of the environmental health indicator. When the question, for example, is aimed at determining hotspots for mitigation actions, detailed noise maps would suffice, while the evaluation of the health impact (retrospective or prospective) of noise of mitigating actions demands a HIA by means of an indicator summarizing the impact of noise on different health outcomes. Three decisions have to be made before an indicator can be chosen: are the assumptions underlying the indicator not violated, is the expertise available to apply the indicator and what would be the preferred way to present the results bearing in mind the specific aim of the calculations, the relevant scale level and the target population.

3.3 Environmental health indicators

In the methods to map environment and health a distinction can be made between more qualitative and more quantitative methods.[4] Broadly, a distinction can be made between the following types of (summary) environmental health indicators: 1. Noise Exposure based indicators 2. Environmental quality indicator of noise level 3. Integrated environmental quality indicator 4. Number of people affected NafP (annoyed, disturbed, etc) 5. Integrated health indicators (magnitude of the total health effects on people) 6. Other indicators mixing exposure and/or health effects with population characteristics (like deprivation, demography, etc.). These indicators all have advantages and disadvantages. For further analysis the following indicators were selected: I Compliance with the WHO Noise Guidelines II Health effect screening III Cumulative Health based Environmental Risk Indicator IV Number of people affected and V Disability adjusted Life Years. There is a certain hierarchy: the indicators move from more simple, qualitative methods (I, II), towards the more complex ones which quantify exposures and effects, or integrate effects (III-V). The selection was primarily based on their potential to describe the health effects of exposure to environmental noise in

the general population.

Based on the literature [5-7] and consultation with experts the following set of criteria was developed, guiding the selection of indicators per Health Impact Assessment:

The indicator has to be:

1. Relevant to quantify health effects of noise
2. Relevant for policy use
3. Capable to reflect changes in noise exposure
4. Flexible and adaptable to new ERF's, severity weights and guideline values
5. Scientifically sound
   a. Unbiased (not affected by other parameters than noise)
   b. Reliable (in the sense that it is robust and unaffected by minor changes)
   c. Acceptable (in the sense that it is widely used, not widely criticized)
6. Based on available data of acceptable quality
7. Easy to implement
8. Understandable for the general public

3.4 Final selection of indicators for the END Guidance document

In the next step the indicators and criteria were evaluated by a group of international experts and policy makers making use of the Delphi method with three consultation rounds: In total twenty people have been invited to participate in the first Delphi Round of whom twelve responded. Results are shown in figure 3.3.

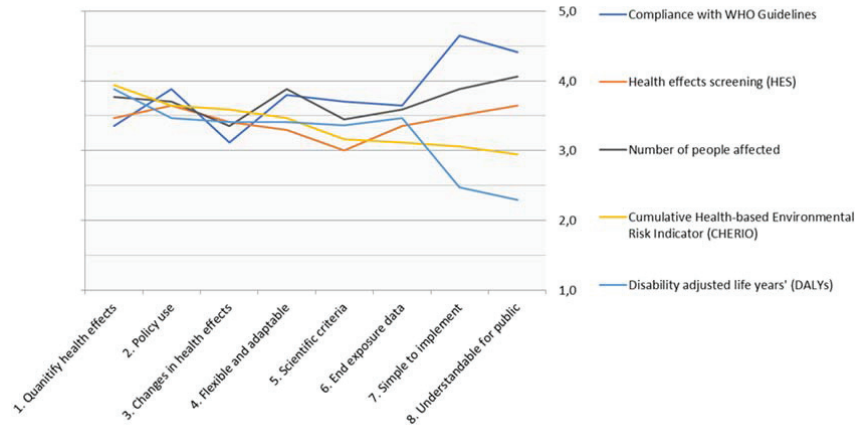

Figure 3.3: Scoring of the five indicators on eight criteria

Results show that overall the scoring does not differ that much between the five indicators; the largest contrasts between indicators are found on criteria 7 and 8 pertaining to simplicity of implementation and comprehensibility to the general public. Compliance with the WHO guidelines (I) scores highest on these requirements and the DALY (V) the lowest. Requirement 6 (END exposure data) discriminates least between the five indicators. Taking the two requirements of the European Commission into account (preferably indicators which summarize the different outcomes and at least include the DALY), the NafP and the DALY were selected as the key indicators to be elaborated on in the Guidance document part B and the practical example in Dusseldorf (part C not included here).

4. GUIDANCE DOCUMEN PART B: Calculations

4.1 Steps in the calculations

The actual process of calculating the burden of disease discerns five steps. In view of space these steps can only be summarized and the actual calculations will be restricted to the NafP . These steps include: selection of health outcomes (step 1, see also Figure 3.1). Next the input values that should be included in the calculations are described; the assessment of population exposure (step 2); the

identification of exposure response relations (step 3); the estimation of the number of cases (step 4) and the calculation of the disease burden (step 5).

Step 1: Selection of health indicators

Based on the recently published WHO reviews[8-14] the outcomes a-priori considered for inclusion in the HIA all had an ERF for noise indicators L_{den} and/or L_{night} to relate the noise exposure to the health outcome. In this paper only sleep disturbance will be described in more detail.

There is sufficient evidence [8] for sleep disturbance due to environmental noise to be included in the HIA for the END. In studies investigating the association between noise and sleep disturbance, the percentage of the population highly sleep disturbed (%HSD) is based on a standardized survey question referring to noise (per source).

For sleep disturbance at present the percentage of highly sleep disturbed (%HSD) is recommended as the preferred indicator.

The source-specific ERFs for sleep disturbance show considerable variation over time and between studies. This indicates that deviations in the %HSD can occur at national/regional/municipal level as compared to %HSD calculated using the generalised ERFs described in this document

In order to assess the actual number of highly sleep-disturbed people in a study area in the framework of a Noise Action Plans (NAPs), it is recommended to use local data if available: the results of survey data or ERFs based on local data. In case these data are not available, generalized ERFs can be applied. In order to compare the effectiveness of (policy) actions or to prioritize actions in the framework of a noise action plan in terms of an increase/reduction in the fraction of highly sleep disturbed annoyed people, generalized ERFs can be applied because the comparison is relative.

Step 2: Input data sets

In order to calculate the number of DALYs (step 5), several data are needed including the incidence of effects (in this case the number of highly sleep disturbed people per year attributable to noise). In order to calculate these, for sleep the following input data is needed for the study area: 1).The fraction and number of residents per noise category 2).Demographic data of the study area.

Fraction and number of residents per noise category In combination with fixing the boundary of the study area carefully the noise exposure distribution of the population living in the study area is one of the essential pre-requisites, necessary to quantify the DALYs by environmental noise exposure in a given area. Given that the study area and study period have been determined, population exposure data can be obtained in several ways. When the focus is on a limited area and population, noise exposure could be assessed by direct measurements. But for larger populations and longer periods (which is usually the case in a health impact assessment), noise exposure is usually assessed by means of calculations using models, that focus on the noise levels at the façades of the dwellings averaged over a year.

In quantifying the NafP or DALYs the exposure of the population is the starting point. For the interpretation of the findings it would be helpful to study the (cumulated) maps of the selected area in addition to the tables also for the lower exposure levels. An extra advantage of producing a map of the exposure situation is that it illustrates where the hotspots in the study area are located. At the same time this can give an indication of future health effects.

Demographic data of the study area can usually be obtained from the national statistics agencies. In case the national statistics agency does not produce population estimates, the statistical office of the European Union (EUROSTAT) is a reliable alternative, that can provide demographic data at both country and regional level (http://ec.europa.eu/eurostat/).

Step 3: Exposure response relations for sleep disturbance. *Definition: A disorder of sleep patterns which may be high enough to interfere with a person's normal physical, mental and emotional functioning, comparable to insomnia* ***(ICD-10: F51).*** The actual percentage or number of highly sleep disturbed people in the study area can be assessed directly by means of a survey, using a standard question comparable to ISO/TS 15666:2003, among a representative group of people living in the study area. The actual number of highly sleep disturbed people can also be assessed indirectly, by

means of calculations where source-specific ERFs are combined with population exposure distributions. ERFs can be based on data from local studies of sufficient quality or from the generalised Erf. In case ERFs based on local data are not available, one could assess the percentage or number of highly sleep disturbed people by applying generalized ERFs. It is also possible that instead of presenting the actual situation, it is needed to prioritise/choose between mitigating measures. In that case both ERFs based on local data and generalized ERFs can be applied, depending on what is available. The most recent generalised source-specific exposure response equations for highly sleep disturbed are presented in Figure 4.2.

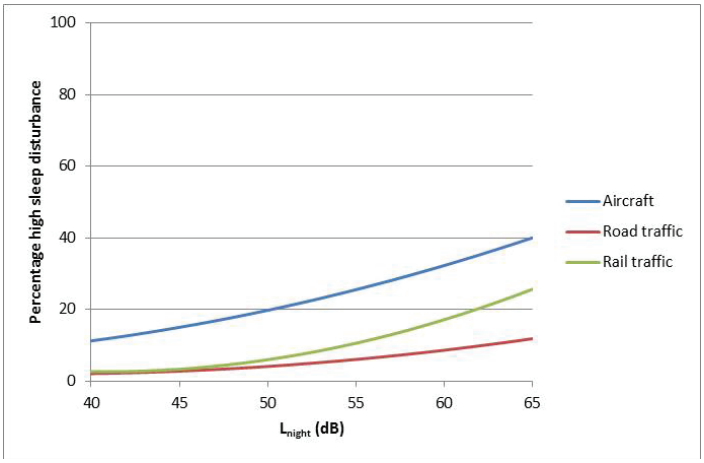

Figure 4. 2 Percentage of highly sleep disturbed from aircraft, road traffic and railway noise[8]

Step 4 and 5: Calculations of number of people with high sleep disturbance
For the actual formulas we refer to the full publication

4.2 In – or exclusion of Annoyance and sleep disturbance in DALY calculation?

While both high sleep disturbance and high annoyance were part of the WHO estimate of the burden of disease due to environmental noise [15], a later document excluded annoyance and included high sleep disturbance using the ICD code for insomnia.[16] In the literature several arguments can be found why annoyance might not qualify as a health endpoint in DALY calculations. Of these, the most prominent is that annoyance does not have an ICD9 or ICD10 code.[17, 18] However, there are many arguments to include annoyance, as a very important end point in itself and a determinant of stress related long term effects. When deciding to include high annoyance and high sleep disturbance in the DALY calculations, one has to be aware that the resulting DALYs cannot necessarily be compared with DALYs calculated according to the new GBD method, which currently does not include high annoyance nor high sleep disturbance. Since the Bod noise report[15,16] the methodology of the assessment of DWs for burden of disease studies has been improved and standardised. In 2015 a study was published with DWs for Europe for a set of 255 health states among a representative population of about 30,000 people from four European countries.[19] For insomnia a DW of 0.023 was estimated with a confidence interval of 0.017 to 0.028. Based on the latest results [19] a DW disability weight for highly sleep disturbed of 0.0175 is recommended (0.63 to 0.90 times the disability weight of primary insomnia).

5. CONCLUSIONS

Based on the latest evidence this paper summarized the Guidance document, aimed at giving guidance regarding the inputs needed for a HIA. With a stepwise explanation of the methodology and actual calculations of health impacts of noise, the document hopes to support local authorities to quantify the health impacts of their noise action plans and compare the impact against alternative solutions.

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REFERENCES

1. WHO World Health Organization. Environmental noise guidelines for the European region (2018)
2. Babisch W, Dutilleux G, Paviotti M, Backman A, Gergely B, McManus B, Bento Coelho L, Hinton J, Kephalopoulos S, van den Berg M, Licitra G. Good practice guide on noise exposure and potential health effects. European environmental agency (EEA) Technical report. 2010(11):2010
3. Brown AL and Kamp I van, WHO Environmental noise guidelines for the European Region: a systematic review of transport noise interventions and their impacts on health. International Journal of Environmental Research and Public Health, 2017. 14(8): p. 873.
4. Fast, T(2016) Instrumenten gezondheid en leefomgeving Fast Advies in Dutch
5. Briggs D, Corvalan C, and Nurminen M, Linkage methods for environment and health analysis. General guidelines. A report of the Health and Environment Analysis for Decision-making (HEADLAMP) project. 1996, United Nations Environment Programme, United States Environmental Protection Agency, World Health Organization: Geneva.
6. van Kempen, Beoordeling van gezondheid in de Milieueffectrapportage Advies aan het Ministerie van Verkeer en Waterstaat RIVM Rapport 630015001/2009 in Dutch only.
7. The Local Government Management Board, United Kingdom, 2016.
8. Mathias Basner and Sarah McGuire WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep Int. J. Environ. Res. Public Health 2018, 15(3), 519; doi:10.3390/ijerph15030519
9. Guski R, Schreckenberg D, Schuemer R. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Annoyance. International journal of environmental research and public health. 2017 Dec 8;14(12):1539.
10. Clark C, Paunovic K. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Cognition. International journal of environmental research and public health. 2018 Feb 7;15(2):285.
11. Kempen van EEMM, et al., Cardiovascular and metabolic effects of environmental noise. Systematic evidence review in the framework of the development of the WHO environmental noise guidelines for the European Region. 2017, RIVM: Bilthoven.
12. Kempen van EEMM, Casas M, Pershagen G, Foraster M. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Cardiovascular and Metabolic Effects: A Summary. International journal of environmental research and public health. 2018 Feb 22;15(2):379.
13. Nieuwenhuijsen MJ, Ristovska G and Dadvand P. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Adverse Birth Outcomes. Int. J. Environ. Res. Public Health 2017, 14(10), 1252; doi:10.3390/ijerph14101252
14. Śliwińska-Kowalska, M and Zaborowski K. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Permanent Hearing Loss and Tinnitus. Int. J. Environ. Res. Public Health 2017, 14(10), 1139; doi:10.3390/ijerph14101139
15. WHO (2011): Burden of disease from environmental noise. Copenhagen.
16. WHO Regional Office for Europe. Methodological guidance for estimating the burden of disease from environmental noise. Hellmuth T, T Classen, R Kim and S. Kaphalopoulos (editors). WHO Regional Office for Europe, 2012
17. Murray CJL, et al., Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease study 2010. The Lancet, 2012. 380: p. 2197-2223.
18. Mathers CD, Vos T, Lopez AD, Salomon J, Ezzati M (ed.) 2001. National Burden of Disease Studies: A Practical Guide. Edition 2.0. Global Program on Evidence for Health Policy. Geneva: World Health Organization.
19. Haagsma JA, et al., Assessing disability weights based on the responses of 30,660 people from four European countries. Population Health Metrics, 2015. 13: p. 10