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Environmental burden of disease due to transportation noise in Flanders (Belgium)

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ABSTRACT

Exposure to environmental noise due to transport affects public health. Cardiovascular diseases, sleep disturbance and annoyance are the most-reported harmful effects of noise exposure. Here, the burden of disease due to transportation noise in Flanders is quantified based on the disability adjusted life year methodology (DALY), combining the burden due to premature death and disability in a single index. The estimated number of DALYs due to transportation noise in Flanders in 2004 was 20,517, corresponding to 1.7% of the burden of disease in Flanders or 21.8% of the environmental burden of disease due to particular matter, ozone, carcinogenic air pollutants and noise. Nevertheless, the results must be interpreted carefully because of the rather large uncertainty range attributable to the variety in exposure level, the uncertainty of exposure–response functions and the choice of the severity weight.

1. Introduction

Due to urbanization, economic growth and motorized traffic, noise is widespread in the present day society. Environmental noise, caused by traffic, industrial and recreational activities is one of the main local environmental problems in Europe and the source of an increasing number of complaints from the public (Berglund et al., 1999). In a review article Passchier-Vermeer and Passchier (2000) concluded that there was sufficient evidence for a causal relationship between noise exposure and hearing impairment, hypertension, ischemic heart disease, annoyance and sleep disturbance. Throughout the recent years the evidence has increased (Babisch, 2006). The European Directive on Environmental Noise (Directive 2002/49/EC 2002) provides a common basis for tackling the noise problem across the European Union based on avoiding, preventing or reducing the harmful effects on a prioritised basis. Consequently, harmonised indicators are necessary to determine the noise exposure and to inform the public about their harmful health effects. Hofstetter and Hammitt (2002) argue strongly for aggregated, one-dimensional environmental health indicators, incorporating health effects like mortality, morbidity and less of well-being such as willingness-to-pay, quality adjusted life years or disability adjusted life years. After all, a myriad of different health effects exists and given the restricted resources available to protect health, there is a need to weight different risks and to allocate resources to get the maximum benefit (Künzli et al., 2000). This paper focuses on the most widely-used indicator 'disability adjusted life years' (DALYs).

The DALY was introduced by the World Bank and the World Health Organization (WHO) in the "Global Burden of Disease" study to quantify the loss of health in different regions of the world, and to allow comparisons between regions and continents (Murray and Lopez, 1996). The initial approach has prompted a series of country-level studies, national burden of disease and risk-based environmental burden of disease studies. The last describes the fraction of disease burden attributable to

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an environmental risk factor. Environmental burden of disease studies allow policies to based on estimated health gains and efficient resource allocation (Anand and Hanson, 1998). Key advantages of the DALY include its aggregate nature combining quantity (premature mortality) and quality of life (time spent with disability), as well as its possibility to compare various risk factors and diseases with the burden of disease in other areas (de Hollander, 2004). Notwithstanding its increased use, the DALY indicator is not without its critics. Many have focused on the specific assumptions concerning the disability weight, notion of values, quality of data and inequity as a result of age-weighting and discounting (Fox-Rushby, 2002).

The burden of disease related to noise exposure has seldom been estimated. Knol and Staatsen (2005) calculated 2300 ($CI_{90\%}$: 1100–4700) DALYs per million people of transportation noise exposure in the Netherlands in 2000, taking into account hypertension, cardiovascular diseases, severe annoyance and sleep disturbance. During a World Health Organization (2005) expert consultation, Müller-Wenk reported the perceived sleep disturbance due to transportation noise in Switzerland in 1995 was 2800 DALYs per million people. Here, the transportation noise burden of disease, expressed in DALYs, is calculated for Flanders and compared with the data in the Netherlands, Switzerland and the burden of disease in Flanders.

2. Methodology

Here, noise is restricted to that emitted from road traffic, trains and aircraft. Noise caused by industrial and recreational activities is excluded because these sources are too location specific. The transportation noise burden of disease in Flanders estimate is based on the DALY methodology applied by Knol and Staatsen (2005) in the Netherlands and preliminary World Health Organization (2005) work, without age adjustments or time discounting (Prüss-Üstün et al., 2003),

$$\mathrm{DALY} = \mathrm{YLL} + \mathrm{YLD} \tag{1}$$

where YLL = number of deaths (N) × (disability weight DW) × standard life expectancy at age of death in years (L) and YLD = number of incident cases (N) × disability weight (DW) × average duration of disability in years (L).

First, the health effects and well-being impacts due to environmental noise exposure are selected based on epidemiological studies and exposure data in Flanders. Two types of health end-points can be distinguished (de Hollander et al., 2004). The social–psychological effects or well-being effects due to noise exposure include annoyance, psychosocial well-being, psychiatric hospitalization, impairment of cognitive performance, sleep disturbance, communication and concentration disturbance, fear and anger (Miedema, 2007; Stansfeld et al., 2005). Examples of the clinical end-points or well-defined diseases are hypertension, ischemic heart diseases and hearing impairment. Here, only severe annoyance, severe sleep disturbance, hypertension and ischemic heart diseases are taken into account. The other end-points are not quantified because of a lack of suitable health statistics or limited scientific evidence. Mild disturbances of sleep, concentration and communication are also dependent on coping style, personal factors and situational variables, and are also omitted.

Second, the exposure assessment is based on the day–evening–night levels (L_{den}) and the night levels (L_{night}), stratified in 5 dB groups, caused by transport noise (road traffic, aircraft due to Brussels National Airport and railway traffic) on Flemish territory in 2004 (Botteldooren et al., 2005).

The information on exposure is combined with estimates of exposure–response relationships (Miedema and Oudshoorn, 2001) and survey data (Bayingana et al., 2004; Aminabel, 2004) to determine the prevalence of highly annoyed people. The prevalence of sleep disturbance due to rail and road traffic in Flanders is based on exposure–response relationships calculated by Miedema et al. (2003). Sleep disturbance due to aircraft noise is not taken into account because of the large individual variance and uncertainty range (Miedema and Vos, 2004, 2007). The prevalence data for hypertension and ischemic heart diseases are based on the Intego database, a registration network for family practices (www.intego.be). Anonymous information about patient contacts, diagnoses, laboratory results and drug prescriptions are systematically recorded in this central database. The prevalence of hypertension is also estimated on the results of the Belgian National Health Interview Survey in 2004 (Bayingana et al., 2004). The relative risks derived from a meta-analysis of van Kempen et al. (2002) are used to calculate the attributable fraction of the population suffering from hypertension and ischemic heart diseases caused by transportation noise.

Finally, the attributable fraction of people affected is multiplied by the average duration of the effect and a severity weight. The duration is based on the number of healthy life years lost. Assuming that people will be annoyed and sleep disturbed throughout the year, the duration of severe annoyance and sleep disturbance is set to 1 (Knol and Staatsen, 2005). Because of the assumption of chronic exposure, the duration of hypertension and IHD was considered to be 1 year. The severity weight refers to a set of disease specific empirical weights, based on medical experts' judgments, to value the level of disability on a scale from 0 (perfect health) to 1 (death). The disability weight for hypertension and ischemic heart diseases is set at 0.352 (Mathers et al., 1999) and 0.35 (de Hollander et al., 1999). For serious sleep disturbance and severe annoyance a severity weight of 0.01 with a large uncertainty range (0.002–0.012) is selected based on van Kempen (cited in Knol and Staatsen, 2005) and de Hollander et al.

3. Results

Regarding severe annoyance, the prevalence of annoyed people caused by transportation noise varies from 9.3% to 11.8% using the empirical data of the Health Interview Survey and the Written Environmental Investigation survey, respectively.

Based on the exposure–response relationships of Miedema and Oudshoorn (2001), 627,838 people are severely annoyed, some to 10.57% of the Flemish population. The prevalence of annoyance due to air traffic is 10 times higher using data from the Health Interview Survey. While the survey takes into account aircraft noise in the Flemish region, the exposure–response function for air traffic is only applied around Brussels National Airport. The healthy years of life lost varies between 93,000 and 118,000 DALYs per million habitants. The relatively large variance between the lowest and highest estimation can be ascribed to the large variance of the disability weight and the methodology used to calculate the prevalence of severed annoyed people in Flanders due to transportation noise. Road traffic has the highest impact on severe annoyance: between 73,000 and 91,600 DALYs per million habitants using the Belgian Health Interview Survey and the exposure–response relationships.

In 2004, 391,894 people suffered from severe sleep disturbance due to road and railway traffic, corresponding to 6.6% of the population. The healthy life years lost due to sleep disturbance varies between 132 and 6597 DALYs per million habitants. The large distribution can be explained by the uncertainty range of the disability weight (0.002–0.1). Road traffic has the highest contribution to these DALYs (81%).

The proportion of Flemish people suffering from hypertension due to transportation noise exposure in 2004 was to 3.71% of the total cases. Dependent on the relative risk and the data source, the attributable number of cases varies from 12,526 to 34,369 using the Intego databank and from 14,714 to 40,372 calculated for the Belgian Health Interview Survey. Consequently, the data source also influences the years of healthy life lost due to hypertension caused by noise exposure varying from 731 to 858 DALYs per million habitants calculated for the Intego database and from 2005 to 2355 DALYs per million habitants using the Health Interview Survey. Road traffic has the highest contribution to the total healthy life years lost (93%). The prevalence of ischemic heart disease due to road noise exposure in Flanders varies between 1304 and 3377 in 2004, and the related number of healthy life years lost varies between 77 and 199 DALYs per million habitants.

The environmental noise burden of disease in 2004 corresponded to 3420 DALYs per million habitants (1274–21,640) using the exposure–response relationships of Miedema and Oudshoorn (2001) and Miedema et al. (2003) for severe annoyance and the prevalence data of the Health Interview Survey for hypertension. Related to the burden of disease (1,200,000 DALYs) calculated by Baert et al. (2001), the proportion of the environmental noise burden of disease is 1.71% (0.63–10.75%). In comparison with healthy life years lost due to outdoor air pollution caused by PM_{10}, $PM_{2.5}$, ozone, Pb, Rn, Ni, As, PAHs, benzene and UV (Bossuyt et al., 2007), transport noise amounts to 21.8% of the environmental burden of disease attributable to air and noise pollution in Flanders.

4. Conclusions

The environmental noise burden of disease in Flanders in 2004 amounts 20,517 DALYs, corresponding to 1.7% of the burden of disease in Flanders and 21.8% of the environmental burden of disease caused by air and noise pollution. Nevertheless, the results must be interpreted carefully because of large uncertainties attributable to the selected health effects, the variety in exposure level, the uncertainty in exposure–response functions and the choice of severity weight. Unlike the Dutch environmental noise burden of disease study, hypertension based mortality is not included in the analysis to avoid overestimation. Moreover, hypertension and IHD are not only attributable to noise exposure, and cannot be studied independently of other sources like stress, way of life, and genetics. Additionally, the calculated DALYs are not equal to the avoidable number of DALYs. If one cause can be eliminated, the morbidity reduction might not occur because competitive risks are not taken into account.

Because of the uncertainty about the relationship, sleep disturbance due to aircraft is not taken into account although the problem is real in a densely populated region like Flanders. Also the DALYs of annoyance due to air traffic are incomplete because only the area around Brussels National Airport is taken into account, areas around regional airports like Antwerp and Ostend are excluded. The limitation to four health and well-being effects examined means the overall effect of noise on public health is underestimated.

The DALY uncertainty range related to annoyance and sleep disturbance is mainly due to the different disability weights available and the different methodologies to calculate prevalence. The DALY range related to IHD and hypertension is influenced by multiple factors. First, in this study the assumption is made that people suffering from ischemic heart disease or hypertension do not recover and will suffer from it throughout the year. This is plausible when assuming that the exposure is chronic as well. Second, the assumption is made that the exposure–response relationships of van Kempen et al. are applicable to the Flemish situation. Third, L_{den} exposure values are used according to the European Directive on Environmental Noise together with the relative risks estimated by van Kempen. However, these relative risks are based on different noise exposure measures: $L_{\text{Aeq,6–22h}}$ for road traffic noise exposure and air traffic noise exposure is expressed in $L_{\text{Aeq,7–19h}}$. Fourth, the DALY range of IHD and hypertension is also attributable to the prevalence data. The Intego database is composed of registrations of general practitioners. Consequently, only the patients treated are taken in the dataset, which will lead to an underestimation. The prevalence data calculated for the Health Interview Survey will be probably more appropriate, since it is based on a random sample of the population. Fifth, different definitions of hypertension are used in the scientific literature and datasets. In van Kempen et al. meta-analysis of hypertension is defined as a systolic blood pressure $\geqslant$95 mmHg and/or diastolic blood pressure $\geqslant$160 mmHg and/or use of antihypertensives. The surveys used here define hypertension as a systolic blood pressure exceeding 90 mmHg and/or diastolic blood pressure exceeding 140 mmHg. Using the survey data can lead to an overestimation.

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