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BURDEN OF SLEEP DISTURBANCE DUE TO TRAFFIC NOISE IN BULGARIA

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БРЕМЯ НАРУШЕНИЙ СНА ПОД ВОЗДЕЙСТВИЕМ ТРАНСПОРТНОГО ШУМА В БОЛГАРИИ

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ABSTRACT

BACKGROUND: Sleep disturbance is a risk factor for somatic, psycho-social and spiritual dysfunction. It is also arguably the most deleterious effect of traffic noise pollution. Quantification of its burden is an anchor element of environmental policy making but no data are currently available for Bulgaria where the preponderance of dangerous nighttime noise exposure is highest in Europe. **AIM:** The aim of this study was to quantify the socio-economic burden of severe sleep disturbance due to traffic noise (road, aircraft and railway) in Bulgaria. **MATERIAL AND METHODS:** The official World Health Organization methodology used in Europe was applied in order to estimate this annual loss expressed as disability-adjusted life-years (DALYs) and their corresponding monetary value (assuming € 12 000 per DALY). **RESULTS:** Results showed that severe sleep disturbance due to all traffic sources was associated conservatively with 15 468 DALYs (8 839 - 22 097) and € 185 615 861 (€ 106 066 206 - € 265 165 516) lost in 2012, with road traffic being the single most important noise source. **CONCLUSION:** In conclusion, severe sleep disturbance due to traffic noise bears a heavy environmental and socio-economic burden in Bulgaria which prompts vigorous political action and greater involvement in environmental research. In order to increase the accuracy of future burden of disease analyses other studies would need to establish exposure-response functions based on population-based socio-acoustic surveys in the country.

Key words: traffic noise, sleep disturbance, burden of disease, disability-adjusted life-years, environmental economics

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РЕЗЮМЕ

Расстройство сна представляет собой фактор риска, ведущий к соматическим, психосоциальным и психическим нарушениям. Данное обстоятельство вероятнее всего является наиболее вредным последствием шумового загрязнения, источником которого являются транспортные средства. Количественная оценка бремени последствий данных нарушений имеет ключевое значение в отношении политики в области окружающей среды, но на данный момент отсутствует достаточное количество данных по Болгарии, где распространение опасных уровней шумовой экспозиции в ночное время является наиболее высоким в Европе. **Цель:** Целью данного обследования является установление количественной оценки социально-экономического бремени тяжёлого расстройства сна под воздействием транспортного шума (автомобильного, воздушного и железнодорожного) в Болгарии. **Материал и методы:** Прилагается официальная методология Всемирной организации здравоохранения, которая применяется в Европе для оценки ожидаемых годовых потерь здоровых лет жизни, откорректированных на нетрудоспособность (DALYs) и соответствующую им финансовую оценку (при € 12 000 для DALY). **Результаты:** Результаты показывают, что в 2012 г. тяжёлые нарушения сна под воздействием транспортных средств связаны с потерями в 15 468 DALY (8 839 - 22 097) и € 185 615 861 (€ 106 066 206 - € 265 165 516), учитывая при этом, что основным источником шума является уличное движение. **Заключение:** Тяжёлые нарушения сна

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под воздействием транспортного шума являются существенным социально-экономическим бременем для населения и окружающей среды в Болгарии, что со своей стороны предполагает проявление энергичных политических действий и ответственности в отношении исследований окружающей среды. Для достижения большей точности при будущих анализах тяжести следует установить функции, описывающие экспозицию-реакцию на основе популяционно-базируемых социально-акустических исследований в нашей стране.

Ключевые слова: транспортный шум; расстройство сна; бремя заболеваний; здоровые годы жизни, откорректированные на нетрудоспособность (DALY); экономика окружающей среды

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INTRODUCTION

In the Modern World, which daily puts our nervous systems under stress, we fall victims of sensory overload, constantly coping with thinking, remembering, and planning.¹ Sleep is one of the few havens that can sooth our overworked minds and bodies. It is essential for maintaining normal homeostasis, somatic and mental health; it can also be essential for spiritual growth, inner peace and harmony.² Any disturbance of sleep structure, patterns or quality can result in cardio-metabolic impairment, alteration in neuro-hormone secretion and psycho-social dysfunction.³ In addition to social stress interfering with sleep⁴, we face a plethora of environmental stressors pertinent to the modern lifestyle. Transportation noise is arguably one of the most daunting and pervasive of those stressors.⁵ In fact, sleep disturbance is considered the most deleterious non-auditory effect of noise pollution because it is associated with a wide array of non-communicable diseases.⁶

In 2011 the WHO published its “*Burden of Disease from Environmental Noise*” report according to which at least 903 000 disability-adjusted life-years (DALYs) are lost annually to sleep disturbance due to environmental noise in Europe.⁵ Such quantitative evidence is essential for environmental health policy, preparation of national and international noise control agendas and adequate resource allocation. In Bulgaria, however, we lack substantive evidence of the socio-economic burden of traffic noise. It is true that at the time “*Burden of Disease from Environmental Noise*” was published data from South-East Europe were limited, but they are now readily available. Thus the issue needs to be addressed promptly given the major community nuisance that noise pollution has become for Bulgarians⁷ and its egregious preponderance in major agglomerations (> 100 000

inhabitants). According to the Noise Observation and Information Service for Europe (NOISE) (<http://noise.eionet.europa.eu/>), nearly 70% of the citizens of these aggregations are exposed to road traffic $L_{\text{night}} \geq 55$ dB, a threshold above which the WHO considers “[t]he situation [...] increasingly dangerous for public health”³. While other public health risk factors such as the low quality of life⁸, dysfunctional healthcare system⁹ and high prevalence of metabolic syndrome¹⁰ in the country are well-understood and routinely evaluated, the actual contribution of noise pollution to the cumulative burden of disease (BoD) is unknown. Recently, an annual loss of 968 quality-adjusted life-years and € 11.6 million was estimated in the country as a result of road traffic noise-attributed myocardial infarction.¹¹

AIM

In this paper, we aimed to quantify the socio-economic burden of severe sleep disturbance due to traffic noise in Bulgaria.

MATERIAL AND METHODS

This study adopts the official WHO methodology for estimating BoD from environmental noise.⁵ As such, it uses official data and was not subject to ethical evaluation by the University Committee.

The sleep disturbance indicator of interest was “high sleep disturbance” (HSD) and the noise exposure indicator – night equivalent sound level (L_{night}). The burden of HSD was expressed in DALYs lost to traffic noise (road, aircraft and railway). DALYs express “years of life lost to premature death and years lived with a disability of specified severity and duration” where “[o]ne DALY is [...] one lost year of healthy life”.¹² DALYs associated with severe sleep disturbance were calculated according to the formula:

DALYs lost = number of people highly sleep disturbed * disability weight (DW) * duration of exposure

The number of people exposed to different L_{night} noise bands in Bulgaria for 2012 (the most recent year that we had available data for) was extracted from NOISE. Although road traffic is the major source of environmental noise in Bulgarian agglomerations, aircraft and railway noise data were also used. Our analyses were restricted to the exposure range 55 dB to ≥ 75 dB, where the upper limit of the highest category was set at 80 dB. The percentage of high sleep disturbance (%HSD) was calculated at the midpoint of each category as a function of L_{night} , according to the polynomial approximations reported by Miedema et al.¹³

$$\text{Aircraft: \%HSD} = 18.147 - 0.956*(L_{\text{night}}) + 0.01482*(L_{\text{night}})^2$$

$$\text{Road traffic: \%HSD} = 20.8 - 1.05*(L_{\text{night}}) + 0.01486*(L_{\text{night}})^2$$

$$\text{Railways: \%HSD} = 11.3 - 0.55*(L_{\text{night}}) + 0.00759*(L_{\text{night}})^2$$

%HSD above 70 dB was assumed to be constant (i.e., equal to the %HSD in the 65 – 69 dB category). Duration of exposure was set at one year and, since sleep disturbance does not directly

result in premature death, years of life lost were set to zero.⁵ A disability weight (DW) of 0.07 was chosen with an uncertainty range 0.04 – 0.10.⁵ DW represents a value preference that scales a condition/state from 0 (full health) to 1 (death).¹²

Finally, we monetized the value of these DALYs by conservatively setting the value of one DALY at the gross domestic product (GDP) per capita in Bulgaria for 2012, according to the method proposed by Brown.¹⁴ This value was 12 000 Purchasing Power Standards (PPS)¹⁵, (“fictive ‘currency’ units that remove differences in purchasing power”¹⁶ and roughly equal to one euro in the EU-28). All formulae were entered in Microsoft Excel v. 2010 spreadsheet.

RESULTS

BoD was first quantified for each of the three traffic noise sources (road, aircraft and railway) expressed as DALYs and corresponding monetary value, and then summed to give a conservative estimate of the total socio-economic cost of severe sleep disturbance in Bulgarian urban population. Table 1 presents results on road traffic noise which is the dominant cause of traffic noise-attributed sleep disturbance in the country. People exposed to $L_{\text{night}} \geq 55$ dB constituted about 68% of the studied urban population. Eight percent of those people were highly sleep-disturbed. Even in the most conservative scenario (DW = 0.04), the latter were associated with

Table 1. Disability-adjusted life-years and monetary valuation for highly sleep-disturbed people due to road traffic noise in Bulgaria

Exposure category L_{night} [dB(A)]	People exposed in the population (%)	People highly sleep-disturbed in the category (%)	DALYs lost in the urban population of major agglomerations (n = 2 568 250)		
			0.04	0.07	0.10
55 – 59	776 100 (30.22)	74 163 (9.56)	2 967	5 191	7 416
60 – 64	763 200 (29.72)	100 909 (13.22)	4 036	7 064	10 091
65 – 69	193 600 (7.54)	34 133 (17.63)	1 365	2 389	3 413
70 – 74	22 300 (0.87)	3 932 (17.63) ^a	157	275	393
≥ 75	1 200 (0.05)	212 (17.63) ^a	8	14	21
Total number of DALYs lost			8 534	14 934	21 335
Monetary valuation of DALYs lost (in PPS euro)			102 407 580	179 213 265	256 018 951

Note. Data are extracted from Noise Observation and Information System for Europe and refer to 2012. The monetary value of one DALY is set at € 12 000. Duration of exposure is assumed to be 1 year. ^aThe percentage of people highly sleep-disturbed above 70 dB is assumed to be the same as in the 65 – 69 dB category. The figures are rounded. DW – disability weight, DALYs – disability-adjusted life-years, L_{night} – nighttime equivalent sound level, PPS – Purchasing Power Standards.

Table 2. Disability-adjusted life-years and monetary valuation for highly sleep-disturbed people due to air traffic noise in Bulgaria

Exposure category L_{night} [dB(A)]	People exposed in the population (%)	People highly sleep-disturbed in the category (%)	DALYs lost in the urban population of major agglomerations (n = 2 568 250)		
			0.04	0.07	0.10
55 – 59	35 100 (1.55)	4 274 (12.18)	171	299	427
60 – 64	13 000 (0.57)	2 117 (16.29)	85	148	212
65 – 69	0 (0)	0 (0)	0	0	0
70 – 74	0 (0)	0 (0)	0	0	0
≥ 75	0 (0)	0 (0)	0	0	0
Total number of DALYs lost			256	447	639
Monetary valuation of DALYs lost (in PPS euro)			3 067 697	5 368 470	7 669 243

Note. Data are extracted from Noise Observation and Information System for Europe and refer to 2012. The monetary value of one DALY is set at € 12 000. Duration of exposure is assumed to be 1 year. The figures are rounded. DW – disability weight, DALYs – disability-adjusted life-years, L_{night} – nighttime equivalent sound level, PPS – Purchasing Power Standards.

Table 3. Disability-adjusted life-years and monetary valuation for highly sleep-disturbed people due to railway traffic noise in Bulgaria

Exposure category L_{night} [dB(A)]	People exposed in the population (%)	People highly sleep-disturbed in the category (%)	DALYs lost in the urban population of major agglomerations (n = 2 568 250)		
			0.04	0.07	0.10
55 – 59	16 900 (0.66)	806 (4.77)	32	56	81
60 – 64	6 200 (0.24)	408 (6.57)	16	29	41
65 – 69	200 (0.01)	18 (8.76)	0.7	1	2
70 – 74	0 (0)	0 (0)	0	0	0
≥ 75	0 (0)	0 (0)	0	0	0
Total number of DALYs lost			49	86	123
Monetary valuation of DALYs lost (in PPS euro)			590 929	1 034 126	1 477 322

Note. Data are extracted from Noise Observation and Information System for Europe and refer to 2012. The monetary value of one DALY is set at € 12 000. Duration of exposure is assumed to be 1 year. The figures are rounded. DW – disability weight, DALYs – disability-adjusted life-years, L_{night} – nighttime equivalent sound level, PPS – Purchasing Power Standards.

over 8 000 DALYs and more than € 100 million lost in 2012 alone. Relatively few DALYs could be attributed to air and railway noise, but even so, they translated into at least € 3 – 4 million. (See Tables 2 and 3). A summary estimate of DALYs annual loss is 15 468 with an uncertainty range 8 839 – 22 097; their monetary valuation is € 185 615 861 (€ 106 066 206 – € 265 165 516). These results are conservative and are based solely on

data on approximately 2.57 million people (about 35% of the total Bulgarian population).

DISCUSSION

Traffic noise-attributed severe sleep disturbance in Bulgaria was associated with 15 468 DALYs (8 839 – 22 097) and € 185 615 861 (€ 106 066 206 – € 265 165 516) lost in 2012, with road traffic being the single most important source of noise pollution.

If we compare the estimated burden of severe sleep disturbance to that of myocardial infarction¹¹, we fathom the real threat that traffic noise pollution has become in the country. These figures are quite alarming and mostly due to the high proportion of people exposed to extreme nighttime road traffic noise in major agglomerations. In fact, according to NOISE, Bulgaria has the highest proportion (68%) of people exposed to $L_{\text{night}} \geq 55$ dB in Europe. For comparison, in Germany this is about 15% and in neighboring Romania, just below 40%, with an average of around 25% in Europe.

This study fills a gap in the literature from South-East Europe. A recent review of environmental noise-attributed sleep disturbance in South-East Europe did not identify any research from Bulgaria, but rather from neighboring countries like Macedonia and Serbia.¹⁷ Those studies, however, could not report population-based results on burden of sleep disturbance, since they lacked national level exposure data. Paunovic and Belojević, for example, recently looked at DALYs associated with myocardial infarction attributable to road-traffic noise, noise, but their inferences were limited to Belgrade, due to the small-scale empirical study they conducted.¹⁸ Our results give population estimates and further extend the official WHO methodology by assigning a monetary value to DALYs lost.

However, several limitations of this study should be discussed. First, the WHO methodology is imprecise and gives only a rough estimate of the BoD.⁵ Its inherent uncertainties refer to the extrapolation of exposure-response functions to different populations, validity of self-reported sleep disturbance, accuracy of noise mapping across countries, selection of appropriate DWs, etc. There have been both conceptual and ethical critiques of DALYs, DWs and, generally, putting a quantitative estimate to people's life.¹⁹⁻²¹ Other issues arise from setting the value of one quality-adjusted life year at € 12 000, quality of noise mapping in Bulgaria and the applicability of Miedema et al.'s polynomials¹³ in Bulgaria. Nevertheless, the assumptions made were conservative, including the monetary valuation of DALYs, adopting recommended exposure-response functions, holding %HSD constant above 70 dB, and disregarding people exposed to < 55 dB due to insufficient data, all of which yielded lower estimates than those that would have been derived from a field survey, and therefore rendered our calculations compliant with the conservative principle. Despite the outlined above methodological limitations, the

policy on environmental hazards should be based on the precautionary principle stating that "in cases of serious or irreversible threats to the health of humans or ecosystems, acknowledged scientific uncertainty should not be used as a reason to postpone preventive measures".²²

CONCLUSIONS

Severe sleep disturbance due to traffic noise bears a heavy environmental and socio-economic burden in Bulgaria, being associated with an annual loss of approximately 15 468 DALYs and € 186 million. For a country with limited resources for healthcare, these costs are unacceptable and should prompt vigorous political action and greater involvement in environmental health research. In order to increase the accuracy of future BoD analyses other studies would need to establish exposure-response functions based on population-based socio-acoustic surveys in the country.

CONFLICT OF INTEREST STATEMENT

The authors declare that, with respect to this study, they do not have any potential conflict of interest.

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