Influence of road traffic noise in ischaemic heart disease. Introduction to the issue in Santiago of Chile.

Ismael Gómez [a)]
Max Glisser [b)]
Camilo Padilla [c)]
Acoustic Modeling Department, Gerard Ingeniería Acústica SpA.
Villaseca 21 Oficina 1105, Ñuñoa, Santiago de Chile.

The noise map of Santiago of Chile in 2011 showed that a significant part of its area and population are exposed to road traffic noise levels that are unacceptable or dangerous according to the Organization for Economic Cooperation and Development which Chile belongs to. Considering the multiple potential health effects generated by such exposure, and taking into account that ischaemic heart disease is the second leading cause of death in Santiago, this study quantifies the exposure-response relationship associated with the Population-Attributable Fraction that suffered ischaemic heart disease due to road traffic noise and his respective burden of disease, through the descriptor Disability-Adjusted Life Years developed by the World Health Organization. Therefore, a first introduction to this issue is addressed in this study, by comparing the data with those of studies of other cities and by providing basic background for future analysis.

1 INTRODUCTION

In 2013, approximately 40% of all the environmental complaints in Chile were related to environmental noise[1]. Additionally, this was the second greatest environmental problem for the community of Santiago of Chile after the air pollution[2].

Aligned with the guidelines of the European Union for strategic noise maps[3] summed to the fact that the road traffic noise is the major urban noise source[4], in 2011 the Chilean environmental authority quantified the noise levels due to this source in Santiago of Chile[5]. Later that year, the analysis was deepened to estimate the amount of population exposed to those levels[6,7].

[a)] email: igomez@controlacustico.cl,
[b)] email: mglisser@controlacustico.cl
[c)] email: cpadilla@controlacustico.cl

Environmental noise is a psycho-social stressor that affects subjective well-being and physical health, disturbing communication, concentration, relaxation and sleep[8]. The stress responses associated, result in changes in a number of physiological functions and in the homeostasis of several organs, including blood pressure, cardiac output, blood lipids (cholesterol, triglycerides, free fatty acids, phosphatides), carbohydrates (glucose), electrolytes (magnesium, calcium), thrombosis/fibrinolysis, and others.

A proposed reaction scheme for the effects of noise on the organism is shown in *Fig. 1*. Noise may exert its effects either directly, through synaptic interactions, or indirectly, through the emotional and the cognitive perception of sound. In other words, both the objective noise exposure (sound level) and its subjective perception determine the impact of noise on neuroendocrine homeostasis[9].

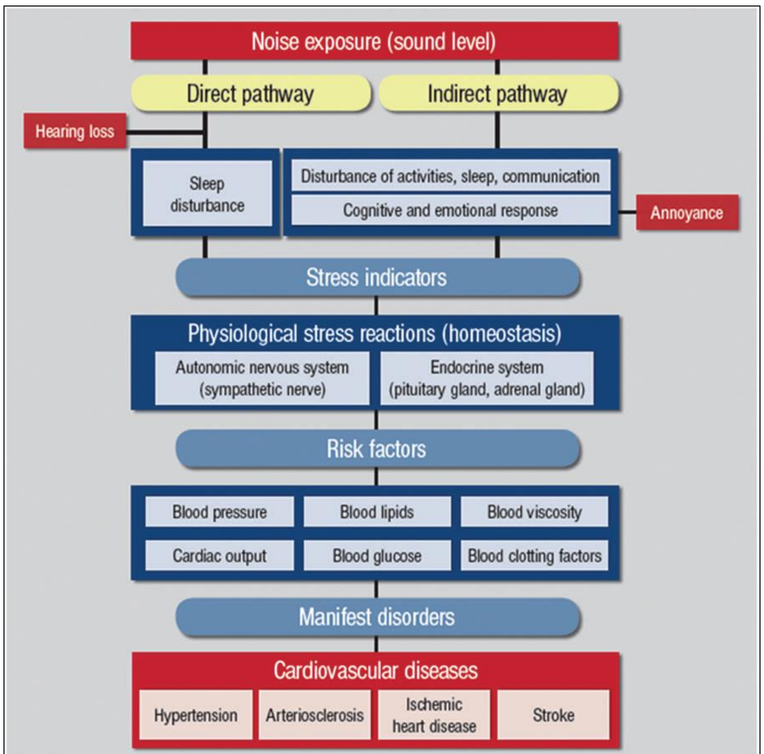

Fig. 1 - Noise effects reaction scheme[9]

Chronic long-term exposure to transportation noise has been shown to be associated with the prevalence and incidence of cardiovascular diseases, including hypertension, ischemic heart diseases (IHD) and stroke[8].

Taking these aspects into account and considering that the IHD's with international classification of disease ICD-10: I20-I25[10], including myocardial infarction (MI), were the second greatest cause of death in Santiago in 2011, only surpassed by cerebrovascular diseases[11], in this study the method of exposure-response relationship developed and validated by the World Health Organization (WHO) and the EU[12] was applied. This method was used to quantify the burden of IHD attributable to road-traffic noise, through the descriptors Population-Attributable Fraction (PAF) and Disability-Adjusted Life Years (DALY). In this way, a first introduction of this issue in Chile has been carried out.

3 METHOD

3.1 Exposure–response relationship

Nowadays, most of the exposure-response functions refer to L_{DEN} (Day-evening-night level) or L_N (Night level), but some still refer to L_D or $L_{D,16h}$ due to the study design they were once validated for[13].

Road traffic noise has been shown to increase the prevalence/incidence risk of IHD, including myocardial infarction (MI). For MI as one major outcome of IHD, the exposure-response functions (Noise levels - Odds Ratios [OR]), refer to a meta-analysis by Babisch[14,15]. Since there is no exclusive causal mechanism postulated specifically to MI, the OR for MI can be applied to all types of IHD according to the Eq. (1) (*Fig. 2*):

$$OR = 1.63 - 0.000613 \cdot \left(L_{D,16h}\right)^2 + 0.00000736 \cdot \left(L_{D,16h}\right)^3 \qquad (1)$$

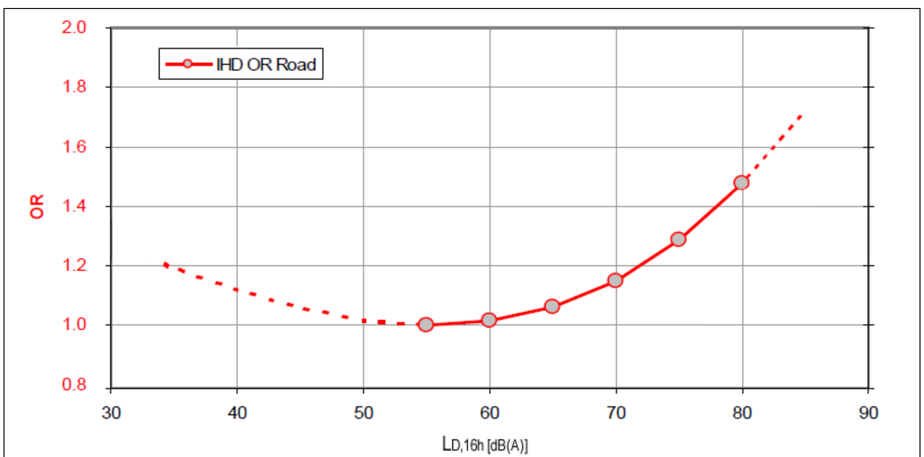

Fig. 2 - Exposure-response functions between road-traffic noise and IHD[13] (own adaptation)

The function is valid for $L_{D,16h}$ noise levels (07:00-23:00 or 06:00-22:00 hours[14]) ranging from 55 dB(A) to 80 dB(A)[13].

In 2011 the Environmental Authority published the noise map of Santiago[5]. This graphical representation consisted of closed polygons (noise areas) defined in steps of 5 dB. In 2013 a geospatial analysis of the noise map was made using Geographic Information System[6,7]. This analysis considered global data from the 2002 population census[16] in addition to dwelling information obtained from the preliminary results of the 2012 census[17]. That study determined the amount of population potentially exposed to noise levels in the thirty-two communes of the province of Santiago in addition to Puente Alto and San Bernardo, codes 13101 to 13132, 13201 and 13401 respectively, according to their Unique Territorial Code[18].

The conclusions of that study were that 62% of the population (3.462.194 inhabitants) are exposed to a day level L_D equal or less than of 65 dB(A), 30% of the population (1.689.245) are exposed to a L_D form 65 to 75 dB(A), while the remainder 8% (458.109) are exposed to levels greater than 75 dB (A) L_D. In the current study these population groups were labeled as group A, group B and group C, respectively.

In the calculations of OR only the groups B and C were considered, assuming –in a conservative way– that the group A population does not have a relative risk associated to IHD, that is to say, it is exposed to noise levels less or equal to 55 dB(A), showing an OR equal to 1; furthermore, it is considered that population from B and C groups is exposed to the lower noise levels in each interval, 65 dB(A) for group B and 75 dB(A) for group C. Both considerations allow a conservative scenario for estimation of OR in each group. Conservative scenario is understood as the use of data in such way that the influence of road traffic noise on IHD is not overestimated.

On the other hand, since the descriptor used as input to calculate the burden of road traffic noise in ischemic diseases is the Day Level (L_D), usually defined as the continuous sound pressure level equivalent in a specific day interval (Eq.(2)) which varies according to the uses of different countries or groups of countries and their respective regulatory requirements. The most common mode is as the level between 06:00 and 22:00 hours[19].

$$L_D = 10Log\left[\frac{1}{16}\sum_{J=1}^{16}10^{\frac{L_{DJ}}{10}}\right] \qquad (2)$$

Where L_{DJ} is the average levels for each daily hour (j).

Nevertheless, it is also defined as the average level between 07:00 and 23:00[12]. Because in the study noise map of Santiago the L_D is defined as the equivalent level between 07:00 and 21:00, it is necessary to determine the influence of using the different period durations on the L_D results. To investigate this, the distribution of daily noise levels in Santiago in the period 1989-2001[20] was taken into account. This distribution is shown in *Fig. 3*.

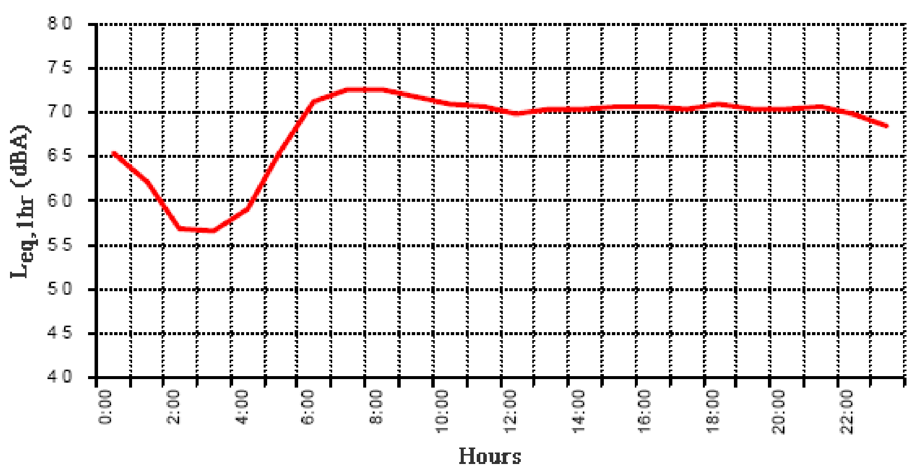

Fig. 3 – Regular daily noise levels in Santiago, Chile (1989 - 2001)

Based on the profile shown above (*Fig. 3*), the level $L_{D,07\text{-}21\ h}$ was adjusted for the periods of times between 06:00 and 22:00 hrs., and between 07:00 and 23:00 hr., noting in *Table 1* the following differences.

Table 1 - Values of L_D for determined periods of time.

Descriptor	Value [dB(A)]	Difference with $L_{D,\ 07\text{-}21\ h}$ dB(A)]
$L_{D,\ 07\text{-}21\ hrs.}$	70.91	--
$L_{D,\ 06\text{-}22\ hrs.}$	70.85	- 0.06
$L_{D,\ 07\text{-}23\ hrs.}$	70.74	- 0.17

In *Table 1*, the highest value corresponds to the descriptor $L_{D,07\text{-}21\ h}$, which is higher just for six hundredths than the obtained value for level $L_{D,06\text{-}22\ h}$, and approximately two tenths to the value associated with the determined interval from 07:00 to 23:00 hrs. However, although the descriptor $L_{D,\ 07\text{-}21\ h}$ is the highest, the differences shown on *Table 1* are considered as negligible, thus they do not affect in a significant manner the final results.

3.2 Population-attributable fraction

The attributable fraction is the proportion of disease in the population that is estimated to be caused by noise. The following formulae can be used to calculate the population-attributable fraction (PAF)[12]:

$$PAF = \frac{\left\{\sum (P_i \cdot RR_i) - 1\right\}}{\sum (P_i \cdot RR_i)} \tag{3}$$

RR_i: Relative risk (OR are estimates of the relative risk) at exposure category *i*
P_i: Proportion of the population in exposure category *i* ($\Sigma Pi = 1$)

If the distribution of exposure and the exposure–response relationship are known, the population-attributable risk (PAR) percentage can be estimated for a population[21]. This way, the population-attributable risk related road traffic noise is calculated by multiplying the PAF with number of subjects with disease for IHD as obtained from the national health statistics[13]:

$$PAR = PAF \cdot N_d \tag{4}$$

N_d: Number of subjects with disease (disease occurrence)

The calculations were carried out using information published by the Ministry of Health through its Department of Health Statistics and Information (DEIS, for its acronym in Spanish), which keeps a detailed data base classified into regions and districts, both expenditures as of deaths segregated by coded diseases by International Classification of Diseases. In addition to that, this data base contains information related to age, gender and occupation, among others.

To obtain the data from the IHD cases, it was necessary to identify the encoded ICD diagnoses between I200 and I259, obtaining a total of 8.837 cases, which 2.383 correspond to deceases. The fatal cases related to men are 1.450, with an age death average of 70.2 years. On the other hand, the deceases related to women are 933, with an age death average of 79.3 years.

All details about the data used and the processing through the R[22] software, can be reviewed in the following link to GitHub account:
https://github.com/Bustami/DALY_IHD_NOISE_STGO_2011

3.3 Disability Adjusted Life Years (DALY)

The use of DALY (Disability Adjusted Life Year) is frequent in order to measure the effect of a disease. The DALY is a summary measure of population health that combines in a single indicator years of life lost from premature death and years of life lived with disabilities. One DALY can be thought of as one lost year of 'healthy' life and the burden of disease as a measurement of the gap between current health status and an ideal situation where everyone lives into old age free of disease and disability[23]. The WHO guidelines[12] were used to calculate DALY's due to road traffic noise (Eq. (5)).

$$DALY = YLL + YLD \tag{5}$$

Where YLL is the number of "years of life lost" calculated by:

$$YLL = \sum_i (N_i^m \cdot \ L_i^m + N_i^f \cdot \ L_i^f) \tag{6}$$

Where N_i^m (N_i^f) is the number of deaths of males (females) in age group i multiplied by the standard life expectancy of males (females) at the age at which death occurs. The information about life expectancy at birth was obtained from the National Statistics Institute[24]. This data is based on five-years period from 1950 to 2025.

Table 2 - Life expectancy at birth, by gender, to five-year periods between 1950 and 2025.

Period	Both gender	Men	Women
1950 1955	54.80	52.91	56.77
1955 1960	56.20	53.81	58.69
1960 1965	58.05	55.27	60.95
1965 1970	60.64	57.64	63.75
1970 1975	63.57	60.46	66.80
1975 1980	67.19	63.94	70.57
1980 1985	70.70	67.38	74.16
1985 1990	72.68	69.59	75.89
1990 1995	74.34	71.45	77.35
1995 2000	75.71	72.75	78.78
2000 2005	77.74	74.80	80.80
2005 2010	78.45	75.49	81.53
2010 2015	79.10	76.12	82.20
2015 2020	79.68	76.68	82.81
2020 2025	80.21	77.19	83.36
Average	**68.99**	**66.15**	**71.95**

YLD is the number of "years lived with disability" estimated by the equation:

$$YLD = I \cdot DW \cdot D \tag{7}$$

Where I is the number of incident cases multiplied by a disability weight (DW) and an average duration D of disability in years DW is associated with each health condition and lies on a scale between 0 (indicating the health condition is equivalent to full health) and 1 (indicating the health condition is equivalent to death).

The analysis considered a value DW=0.35, by the WHO guidelines for years of life lost due to ischaemic heart disease[12,25]. The duration of disability DW was considered as 1, based on the study focused on 2011. The data of IHD cases were obtained from the DEIS data base[11].

Finally, the DALY's were calculated by multiplying the values of YLL and YLD with PAF obtained in 3.2, and then, these values were added. Thus, the resulting value corresponds to the years of potential life lost as a result of road traffic noise in the city of Santiago.

4 RESULTS

Table 3 shows the obtained results of OR for each exposure group defined in chapter 3.1 and the general PAF value for IHD attributable to road traffic noise in Santiago de Chile in 2011.

Table 3 - Results of OR for each exposure group and PAF for IHD and road-traffic noise.

Item	Group A LD,16h < 65 dB(A)	Group B 65 dB(A) < LD,16h < 75 dB(A)	Group C 75 dB(A) < LD,16h
Population [Nº]	3469194	1689245	458109
Population [%]	62	30	8
Relative Risk [OR]	1	1.06	1.29
PAF		**0.03972 (4%)**	

This way, considering conservative assumptions, the PAR for IHD cases attributable to road traffic noise in Santiago de Chile in 2011, was at least 351 persons, of who 94 died.

On the other hand, the total DALYs related to IHD due to the road traffic noise is 185 years, which are divided into 132 years lost for men and 53 years for women (Fig. 4). Both in men and woman, the highest percentage of DALYs were obtained in the key 40 - 49 age group category, which concentrates the 29% of total years lost.

Table 4 shows the values YLL and YLD obtained for each age group category, and as result of the information above, the total of DALYs.

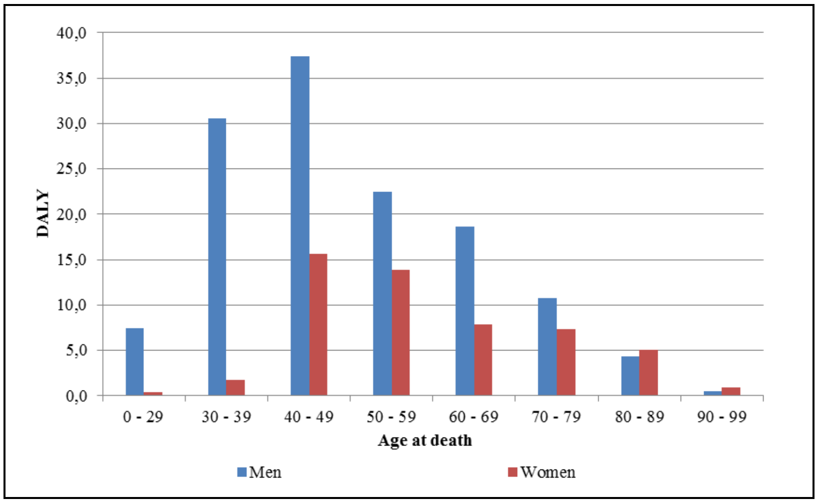

Fig. 4 - DALY due to road traffic noise in Santiago de Chile in 2011.

Table 4 - YLL, YLD and DALYs calculated by age at death categories.

Age at death	YLL	YLD	DALY
0 - 29	6.9	1.0	7.8
30 - 39	29.9	2.4	32.3
40 - 49	43.6	9.4	53.0
50 - 59	14.7	21.6	36.4
60 - 69	0.0	26.5	26.5
70 - 79	0.0	18.1	18.1
80 - 89	0.0	9.4	9.4
90 - 99	0.0	1.3	1.3
Total	**95**	**90**	**185**

In relation to the size of population in the study area, which is 5.398.150 inhabitants, the total amount of DALYs due to road traffic noise is 34 years/million inhabitants, that is, 24 years/million inhabitants for men and 10 years/million inhabitants for women.

5 DISCUSSION AND CONCLUSIONS

Even though in Chile it has taken place studies to diagnose the environmental noise issue, such as strategic noise maps for road traffic noise[5,26], polls for perception of annoyance due to environmental noise[2], environmental complaints tracking[1], among others; the present study is the first approach to calculate the environmental burden of IHD attributable to road traffic noise carried out in the country.

It is noteworthy that there are several sources of uncertainties that could have influenced the results. First, there is an uncertainty that comes from the Santiago noise map[5] in whose production affects a large number of factors such as traffic flow counts, sound emission and propagation models used, and computer programs, among others. On the other hand, the estimated values of the population exposed to different levels in the geospatial analysis noise map of Santiago by Geographic Information System[6] corresponded to a reference study and not conclusive as designated by the environmental authority[7]. Additionally, some inconsistencies were found in the DEIS databases[11], mainly the mismatch between deaths in the expenses forms and similes in the deaths forms. Meanwhile, although the LD used as input to calculate the core values of this study corresponds to an LD 7:00 to 21:00, equations are defined as input the LD 6:00 to 22:00, and as it turned out, its use has negligible for the city of Santiago difference, it should be mentioned. Finally, it should be noted that for calculating the descriptor DALY simplified formula was used, besides considering the weight factor (DW) average for all ischemic and not a disease specific weight factor for each of the diseases.

It should be noted that all adopted assumptions for calculations are based in conservative criteria, which allow to study the problem without overrating it and also to reduce the associated uncertainties at minimal, therefore the effects on health (IHD) of exposed population attributable to road traffic noise, both PAF (4%) as DALY (185) could be greater with a less conservative approach.

Considering all above, in *Table 5* it can be observed that Santiago de Chile has one of the greater PAF values for IHD attributable to road traffic noise in relation to different European countries and cities in the last two decades, being his 2011 value similar to the 90's UE values.

Table 5 - PAF values from European countries and cities trough the time.

Year of the study	Place (Country or city)	PAF [%]
1990	Switzerland[27]	4.5
1994	European Union[27]	4.1
1999	Germany[14,27,28]	2.9 – 3.2
2005	Berlin[12]	1.1
2008	European Union[12]	1.8
2009	Londres[29]	1.8
2011	Paris[30]	3
2011	**Santiago of Chile**	**4**
2012	Bulgaria[31]	2.9
2014	Stari Grad (Belgrado)[32]	2.5

In the same way, the DALYs' calculation was done in unfavourable conditions, in order to not overestimate the possible effect that road traffic noise might cause. Moreover, it allows to deduce that the calculated value could be higher if less conservative conditions are considered. This conclusion is based on the number of premature deaths, which corresponds to 215 cases from a total of 2.383 deceases that is to say, that only the 11% from the fatal cases the age at death is lower than the life expectancy.

Furthermore, the results shown in *Table 4* do not indicate lost years due to a premature death for 59 years old (and older) subjects. The life expectancy considered in this study, implicates that every 55 years old (and older) subject in 2011 had been exceed the life expectancy at birth. As a result, these cases do not implicate the loss of healthy years in both, women and men.

According to the above mentioned, it is deduced that the real life expectancy associated to these age groups are higher, which implicates necessarily an increase related to the lost years due to premature death (YLL). If a 89% of premature deaths corresponds to 2.168 cases, the increase of DALYs could be considered as meaningful.

The results of this study and others of the same type where environmental pollutants are associated with health effects may be important to generate policies and resources allocation as they objectified effects that though perceived by the community and authorities, their numeric representation is highly complex and involves a large amount of factors.

Since this study is a first approach to the problem, it is advisable to carry out more studies to for further deepening in the issue, considering at least the following additional elements: 1) the exposed area and his respective population from others cities of the country, 2) other noise sources like air and train traffic, 3) quantification of the noise impact on different diseases or health aspects, for example sleep disturbance, annoyance, cognitive impairment in children, tinnitus, among others.

It is also advisable to take into account the development of investigations which study the combined effect of noise with other pollutants, like air pollution relation to risk for stroke[33], and the recent studies about the effects of environmental noise in diabetes[34] and of occupational noise and the hearing loss in cardiovascular diseases[35].

7 REFERENCES

1. Superintendencia del Medio Ambiente, Gobierno de Chile, *Informe de Gestión*, División de Desarrollo Estratégico y Estudios, (2013).

2. Ministerio del Medio Ambiente, Gobierno de Chile, *Primera Encuesta Nacional de Medio Ambiente*, (2015).

3. European Parliament and the Council. "Directive 2002/49/EC - Relating to the assessment and management of environmental noise", *Official Journal of the European Communities*, ***Vol. L189****: 12-25* (2002).

4. Conference of European Directors of Roads (CEDR), *Value for Money in road traffic noise Abatement*, Project Group Road Noise (2013).

5. Ministerio del Medio Ambiente, Gobierno de Chile, *Elaboración de mapa de ruido del Gran Santiago mediante software de modelación*, (2011).

6. V. Lobos, R. Quezada and S. Vergara, *Análisis Geoespacial del Mapa de Ruido del Gran Santiago Mediante Sistema de información Geográfico*, (2014).

7. Ministerio del Medio Ambiente, Gobierno de Chile, *Carta DJ Nº 150456/15* (en respuesta a solicitud individualizada con el folio N°21455), Santiago 05 de febrero de 2015.

8. W. Babisch, "Updated exposure-response relationship between road traffic noise and coronary heart diseases: A meta-analysis", *Noise Health*, ***16****:1-9*, (2014).

9. T. Münzel, T. Gori, W. Babisch and M. Basner, "Cardiovascular effects of environmental noise exposure", *European Heart Journal*, **35**: 829–836, (2014).

10. WHO, International Classification of Diseases (ICD), consulted in May 2015: ***http://apps.who.int/classifications/icd10/browse/2015/en***

11. Ministerio de Salud, Gobierno de Chile, Departamento de Estadísticas e Información de Salud, consulted in May 2015: ***http://www.deis.cl/?p=2541 - http://www.deis.cl/?p=1020***

12. WHO Regional Office for Europe, *Burden of Disease from Environmental Noise: Quantification of Healthy Life Years Lost in Europe*, Copenhagen: WHO Regional Office for Europe, (2011).

13. WHO Regional Office for Europe, *Methodological Guidance for Estimating the Burden of Disease from Environmental Noise*, Copenhagen: WHO Regional Office for Europe, (2012).

14. W. Babisch, "Transportation noise and cardiovascular risk: review and synthesis of epidemiological studies, exposure-response curve and risk estimation", Dessau, Federal Environmental Agency, *WaBoLu-Hefte 01/06*, (2006).

15. W. Babisch, "Road traffic noise and cardiovascular risk", *Noise Health*, ***10(38):*** *27-33*, (2008).

16. Instituto Nacional de Estadísticas, Gobierno de Chile, "Censo de Población y Vivienda", (2002).

17. Instituto Nacional de Estadísticas, Gobierno de Chile, "Resultados Precenso 2011. Viviendas Particulares por región y comuna", (2012).

18. Ministerio del Interior, Gobierno de Chile, "Decreto Exento N°817/2010 - Códigos Únicos Territoriales", (2010).

19. ISO 1996-2, "Acoustics - Description and measurement of environmental noise - Part 2: Acquisition of data pertinent to land use", (1987). Reviewed by ISO 1996-1:2003.

20. Autoridad Sanitaria Región Metropolitana, Gobierno de Chile, "Estudio Actualización de Niveles de Ruido del Gran Santiago 1989-2001", (2001).

21. A. Prüss-Üstün, C. Mathers, C. Corvalán and A. Woodward, "Introduction and Methods: Assessing the Environmental Burden of Disease at National and Local Levels", Geneva, World Health Organization, *WHO Environmental Burden of Disease Series,* ***N° 1***, (2003).

22. R Development Core Team, *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL ***http://www.R-project.org****, (2008).*

23. C. Mathers, C. Bernard, K. M. Iburg, M. Inoue, D. Fat, K. Shibuya, C. Stein, N. Tomijima and H. Xu, "Global Burden of Disease in 2002: data sources, methods and results", WHO, *Global Programme on Evidence for Health Policy Discussion* ***Paper N° 54***, (2004).

24. Instituto Nacional de Estadísticas, Gobierno de Chile, “Proyecciones y Estimaciones de Población, Total País”, (2004).

25. A. E. M. de Hollander, J. M. Melse, E. Lebret, and P. G. N. Kramers, “An Aggregate Public Health Indicator to Represent the Impact of Multiple Environmental Exposures”, *Epidemiology*, **10**:606–617, (1999).

26. Ministerio del Medio Ambiente, Gobierno de Chile, *Estudio elaboración de mapas de ruido mediante software de modelación para caso piloto (comunas de Antofagasta y Providencia)*, (2010).

27. R. Kim, “Quantifying burden of myocardial infarction related to environmental noise”, In: *Quantifying burden of disease from environmental noise: second technical meeting report*, Bern, Switzerland, WHO Regional Office for Europe, (2005).

28. European Environment Agency, “Good practice guide on noise exposure and potential health effects”, *Technical report **N° 11**, (2011).*

29. Department for Environment Food and Rural Affairs (DEFRA) UK and Berry Environmental Ltd., “Estimating dose response relationships between noise exposure and human health impacts in the UK”, Supplementary Report: Outline of Possible Valuation Methodology, (2009).

30. BRUITparif Noise observatory in Ile-de-France, ORS Regional Health Observatory in Ile-de-France and WHO Regional Office for Europe, “Health impact of noise in the Paris agglomeration: quantification of healthy life years lost”, (2011).

31. A. M. Dzhambov and D. D. Dimitrova, “Evaluation of the social and economic burden of road traffic noise attributed myocardial infarction in Bulgarian urban population”, *Arh Hig Rada Toksikol **66***, (2015).

32. K. Paunovic and G. Belojević, “Burden of myocardial infarction attributable to road traffic noise: A pilot study in Belgrade”. *Noise Health **16**:374-379, (2014).*

33. M. Sørensen, P. Lühdorf, M. Ketzel, Z. J. Andersen, A. Tjønneland, K. Overvad and O. Raaschou-Nielsen, “Combined effects of road traffic noise and ambient air pollution in relation to risk for stroke?”, *Environmental Research **133**: 49–55*, (2014).

34. M. Sørensen, Z. J. Andersen, R. B. Nordsborg, T. Becker, A. Tjønneland, K. Overvad and O. Raaschou-Nielsen, “Long-Term Exposure to Road Traffic Noise and Incident Diabetes: A Cohort Study”. *Environ Health Perspect **121**:217–222*, (2013).

35. S. A. Girard, T. Leroux, R. Verreault, M. ne Courteau, M. Picard, F. Turcotte, J. Baril and O. Richer, *Cardiovascular disease mortality among retired workers chronically exposed to intense occupational noise*, Int. Arch Occup. Environ Health, Springer-Verlag Berlin Heidelberg (2014).