# Updating of Swiss noise exposure limits based on WHO's Environmental Noise Guidelines evidence reviews and on results from the SiRENE study

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# Updating of Swiss noise exposure limits based on WHO's Environmental Noise Guidelines evidence reviews and results from the SiRENE study

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## ABSTRACT

The present framework for noise abatement in Switzerland was introduced in the 1980s in the Environmental Protection Act. It was subsequently substantiated with noise exposure limits for a range of noise sources. Due to several recent developments, the empirical foundations of the noise limits were increasingly questioned, especially regarding transportation noise. A working group of the Federal Noise Abatement Commission was appointed and commissioned with the task of updating the pertinent scientific foundations and to suggest revised exposure limits when deemed necessary. One result of these efforts was the launch of the interdisciplinary SiRENE study in 2014 with the aim of deriving up to date exposure-response relationships of health effects representative for the Swiss population. At the same time Switzerland has supported WHO's work on new environmental noise guidelines. In its recommendations regarding new noise exposure limits, the working group took into account exposure-response relationships from the (Switzerland-specific) SiRENE study, from the three WHO evidence reviews for annoyance, for sleep disturbance, and for cardiovascular and metabolic outcomes as well as from a recent update of the latter. In deriving limit values, the group followed a similar heuristic as did the WHO for informing their recommendations, but explicitly considered two classes of effects that were both given the same weight for deriving the limit values: Self-reported ("subjective") effects like annoyance and self-reported sleep disturbances on one hand, and on the other hand ("objective") cardiometabolic effects for which the evidence was considered scientifically sound enough, namely ischaemic heart disease (IHD), diabetes, and cardiovascular mortality. In order to define acceptable risks for these outcomes, Disability Weights (DW) came into play. Further empirical data from the SiRENE study were used to define day and night periods, penalties, and, in the case of aircraft noise, noise exposure limits defined as 1-hour Leq values during shoulder hours.

## 1. INTRODUCTION

Today's principle for the protection of the population against noise in Switzerland was laid down in the 1980s in the Environmental Protection Act and was subsequently complemented with noise limit values in the Noise Protection Ordinance. Considerable efforts have since been undertaken to enforce these regulations. Exposure limits cover noise sources such as roads, railways, industry and trade installations, civil and military airports and military training grounds. Most of these limits values were established on the basis of so called socio-acoustic surveys. Since the scientific foundations of the current noise limit values for transportation noise (road, rail and aircraft noise) can be regarded as outdated nowadays, the Federal Noise Abatement Commission developed updated recommendations for noise protection which are intended to provide the Government with the necessary means to formulate or, where necessary, adjust the noise limits so that they meet the pertinent legal requirements. To do so, in a first phase, we drew up the relevant legal bases and reviewed and evaluated the relevant literature in the field of noise epidemiology and noise annoyance. Then we established a systematic step-by-step approach to determine so called generic noise limit values for road traffic, railway and aircraft noise. These values are expressed in the noise exposure metrics Lden and Lnight and are derived based on comprehensive exposure-response relationships on health effects of noise. The generic limit values mark the transition between acceptable and harmful or annoying (in German: "schädlich oder lästig") noise exposure. In a subsequent step, further elements of the Swiss noise rating methodology were analyzed and a limit value scheme was designed in which the generic limit values were transformed into concrete exposure limits. However, the present paper only deals with the derivation of generic limit values.

## 2. METHODS

For the determination of generic limit values in the metrics $L_{den}$ and $L_{night}$, we opted for an approach that was as systematic as possible and not too much guided by

arbitrary settings. Indeed, the procedures we implemented resemble the methodology used by the WHO in the development of the Environmental Noise Guidelines [1], but have been adapted in a few aspects. The individual steps in the process of deriving generic limit values are described in the following.

## 2.1 Step 1: Identification of relevant health outcomes for setting noise exposure limits

Based on a comprehensive literature search, we identified sufficient empirical foundations for deriving noise exposure limits for the following health endpoints:
   a) Annoyance
   b) Self-reported noise-induced sleep disturbances
   c) Cardiometabolic diseases (including deaths caused by them)

These outcomes were considered relevant for the determination of noise limit values for the protection of health and wellbeing. Of course, we were aware that noise can also cause other (health) impediments, e.g. hypertension, cognitive performance impairments, depression and many more. However, these effects were not considered due to a range of reasons, for example, because the quality of the scientific evidence was rated too low.

## 2.2 Step 2: Determination of disability weights and acceptable risks

The Swiss legislation aims to protect people from noise which is "*harmful or annoying*" or *significantly* disturbs people's well-being (Article 74 of the Constitution; Article 15 of the Environmental Protection Act). Thus, an upper limit (in the sense of maximum noise exposure allowed at the receiver) must be defined above which noise effects are considered harmful or annoying.

Due to the indeterminacy of the terms "harmful" and "annoying", they must be made more specific. For this we introduced the concept of maximum *acceptable risk* [2] at which a noise exposure value must be regarded as non-protective anymore (i.e. harmful or annoying in the sense of the Swiss legislation). However, there are no general guidelines for determining acceptable risks, and the range of acceptable risks from environmental noxae is very wide [3]. Adding to the problem is that noise effects research itself does not provide an answer as to the level at which noise exposure (or the health risk associated with it) is no longer "acceptable". Furthermore, continuous exposure-effect relationships, which one normally observes in environmental epidemiology and annoyance research, show no naturally occurring "tipping points" or plateaus which could serve as substantiation for an exposure limit. Deciding for criteria for acceptable risks thus required a well-founded consideration. As a primary guiding principle to determine the acceptable risk, we used disability weights (DWs). A DW is a weight factor that reflects the severity of a disease or condition on a scale from 0 (perfect health) to 1 (equivalent to death). Accordingly, higher acceptable risks were adopted for lower DWs and vice versa, however, we did not follow a strict numerical rule for this conversion but also considered the overall prevalence of an endpoint (e.g. diabetes). It is worth mentioning that in the development of the WHO Environmental Noise Guidelines [1], DWs played a similar role.

In Table 1 the (relative and absolute) risks finally deemed acceptable are listed, for each endpoint, together with the respective DW.

**Table 1:** Adopted disability weights (DW) and acceptable risk (increases) for the five health endpoints considered for the setting of exposure limits, for both the $L_{den}$ and the $L_{night}$ metric

|  | %HA | %HSD | CVD mortality | IHD | Diabetes |
|---|---|---|---|---|---|
| Disability Weight (DW): | 0.02 | 0.07 | 1 | 0.405 | 0.049 |
| Acceptable risk (increase): | 25 % | 15 % | 0.025 | 0.05 | 0.2 |

## 2.3 Step 3: Determination of up to date exposure-response relationships

For all health endpoints defined in Step 1, it was a prerequisite that robust exposure-response relationships are documented in sufficient detail in the literature, either in original studies or meta-analyses and that, in addition to international studies, there is at least one good quality study from Switzerland that describes an exposure-response relationship of the endpoint in question. These criteria limited the usable studies and meta-analyses to just a few. Finally, for the calculation of the generic limit values for the $L_{den}$ metric, we used exposure-response relationships for annoyance (%HA) [4, 5] (including the Swiss SiRENE survey) and studies on cardiovascular (CVD) mortality [6], ischemic heart disease (IHD)

incidence and diabetes incidence [7], including both data from Switzerland and from the WHO evidence review on cardiovascular and metabolic effects [8]. CVD mortality was assessed for the Swiss population using a recent and extended analysis of the Swiss National Cohort (SNC) [6]. The exposure-effect relationships described in [7] are based on a comprehensive update of the original WHO evidence review, and included new original studies which were published up to the year 2019.

For the determination of the $L_{night}$ limit value, we primarily referred to studies on self-reported sleep disturbances [9, 10], using both Swiss data and data from the WHO evidence review on noise effects on sleep. In addition, we considered it useful to apply the exposure-response functions for cardiometabolic and mortality endpoints [6, 7] (see above) also to the night period, that

means to the $L_{night}$ respectively, so that the proposed generic $L_{night}$ limit value is not based exclusively on information on self-reported sleep disturbances. Doing so can be justified by the fact that noise-related

cardiometabolic effects can undoubtedly also be caused by noise exposure during nighttime.

The exposure-response functions or relative risks respectively and reference levels adopted in the process are listed in Tables 2 and 3 below.

**Table 2:** Exposure-response relationships (ERF) / relative risks (RR) per 10 dB increase in exposure [with bibliographic source] and assumed reference levels for the five endpoints considered for the Lden metric

| | | %HA (SiRENE) | %HA (WHO) | CVD mortality | IHD | Diabetes |
|---|---|---|---|---|---|---|
| **Road traffic:** | ERF/RR per 10 dB: | ERF from [4] | ERF from [5] | 1.027 [6] | 1.02 [7] | 1.11 [7] |
| | Reference level [dB] [a]: | – | – | 45 | 45 | 45 |
| **Railways:** | ERF/RR per 10 dB: | ERF from [4] | ERF from [5] | 1.016 [6] | 1.016 [b] | 1.076 [c] |
| | Reference level [dB] [a]: | – | – | 40 [d] | 40 [d] | 45 |
| **Aircraft:** | ERF/RR per 10 dB: | ERF from [4] | ERF from [5] | 1.027 [e] [11] | 1.03 [7] | 1.076 [7] |
| | Reference level [dB] [a]: | – | – | 45 | 45 | 45 |

[a] at the reference level, the relative risk is assumed to be 1.0

[b] General estimator for all noise sources (from the meta-analysis in [7]), since the empirical estimator (RR=1.01, n.s.) would result in an unrealistically high endpoint-related threshold level.

[c] General estimator for all noise sources (from the meta-analysis in [7]), since the empirical estimator would have suggested a protective effect (RR=0.99, n.s.) which was regarded as implausible.

[d] Reference level of 40 dB(A) empirically confirmed [11]

[e] effect estimate refers to myocardial infarction mortality only

**Table 3:** Exposure-response relationships (ERF) / relative risks (RR) per 10 dB increase in exposure [with literature source] and assumed reference levels for the five endpoints considered for the $L_{night}$ metric

| | | %HSD (SiRENE) | %HSD (WHO) | CVD mortality | IHD | Diabetes |
|---|---|---|---|---|---|---|
| **Road traffic:** | ERF/RR per 10 dB: | ERF from [10] | ERF from [9] | 1.027 [6] | 1.02 [7] | 1.11 [7] |
| | Reference level [dB] [a]: | – | – | 35 | 35 | 35 |
| **Railways:** | ERF/RR per 10 dB: | ERF from [10] | ERF from [9] | 1.016 [6] | 1.016 [b] | 1.076 [c] |
| | Reference level [dB] [a]: | – | – | 30 [d] | 30 [d] | 35 |
| **Aircraft:** | ERF/RR per 10 dB: | ERF from [10] | ERF from [9] | 1.027 [e] [11] | 1.03 [7] | 1.076 [7] |
| | Reference level [dB] [a]: | – | – | 45 | 45 | 45 |

[a] at the reference level, the relative risk is assumed to be 1.0

[b] General estimator for all noise sources (from the meta-analysis in [7]), since the empirical estimator (RR=1.01, n.s.) would result in an unrealistically high endpoint-related threshold level.

[c] General estimator for all noise sources (from the meta-analysis in [7]), since the empirical estimator would have suggested a protective effect (RR=0.99, n.s.) which was regarded as implausible.

[d] Reference level of 40 dB(A) in the $L_{den}$ metric empirically confirmed, thus assuming 30 dB for the $L_{night}$ [11]

[e] effect estimate refers to myocardial infarction mortality only

## 2.4 Step 4: Calculation of endpoint-related threshold levels

From the information contained in Tables 1–3 it is possible to determine for each endpoint and each noise source the level at which the previously agreed upon acceptable risk (increase) (cp. Table 1) is met or exceeded. This level will be referred to in the following as the "endpoint-related threshold level" (ETL).

In the next step, for <u>absolute risks</u>, the ETL value was determined at that exposure level at which the acceptable risk (i.e. 25 % HA or 15 % HSD) was just met, based on the underlying exposure-response function.

For the <u>relative risks</u> the ETL value was determined using the references levels and the relative risks per 10 dB increase in exposure from Tables 2 and 3, and the acceptable risk increase from Table 1 (i.e. 0.05 for IHD, 0.025 for cardiovascular mortality, 0.20 for diabetes), according to the following equation and assuming linearity of the exposure-response relationship:

$$ETL= \text{reference level} + \frac{\text{acceptable risk}}{(\text{relative risk per 10 dB increase in exposure - 1})} \times 10$$

As an intermediate result we obtained, for the $L_{den}$, the ETL values for %HA as derived from the SiRENE survey and from the WHO evidence review, and the ETL values for cardiovascular mortality, IHD, and diabetes. Similarly, for the $L_{night}$ metric, we obtained the ETL values for %HSD as derived from the SiRENE study, %HSD as derived from the WHO evidence review, and the respective values for cardiovascular mortality, IHD, and diabetes
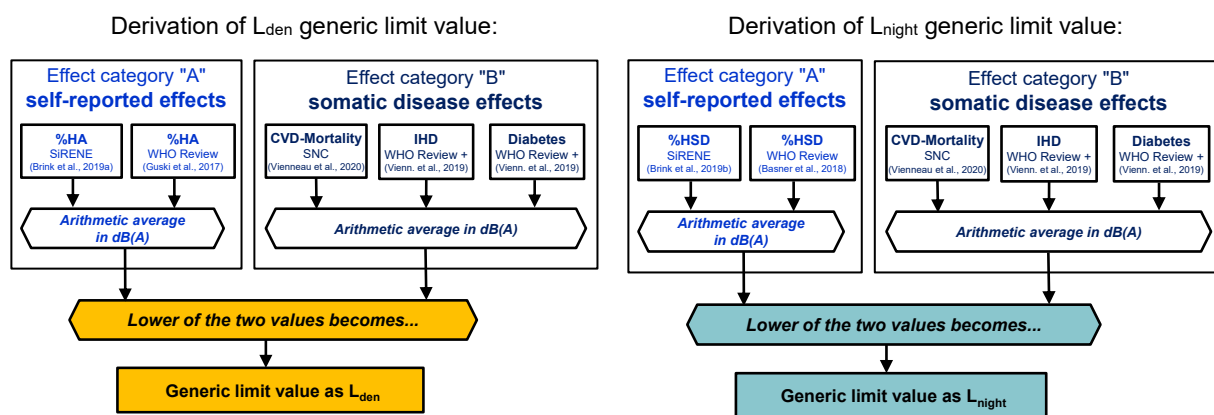


**Figure 1:** Schematic representation of the adopted procedure for determining the generic limit value as $L_{den}$ (left) and as $L_{night}$ (right)

## 2.5 Step 5: Calculation of final limit values

The ETL values resulting from Step 4 can be grouped in two effect categories, a "self-reported effects" category (with 2 ETLs) and and "somatic disease" category (with 3 ETLs). Within each of the two effect categories the ETLs were arithmetically averaged to obtain the exposure limit value for the respective effect category. That means that all endpoints within the effect category contribute to the limit value with the same weight (which seemed appropriate because weighting the different types of effects has implicitly been introduced when adopting acceptable risks in an earlier step). Finally, we determined the generic limit value as the *lower of the two* values. That means that either the average exposure limit from the "self-reported effects" category, or the exposure limit from the "somatic disease effects" category becomes the finally recommended exposure limit. In this way, the derivation of the limit value well considers the legal requirement to limit both the "harmful" as well as the "annoying" effects of noise (cp. Article 13 of the Environmental Protection Act). If physical health effects (i.e. harmful effects) start off at lower levels than self-reported effects, the limit value must be based on these and vice versa. A schematic representation of the adopted procedure for determining the generic exposure limit values for the $L_{den}$ and $L_{night}$ is given in Figure 1.

## 3. CRITICAL APPRAISAL

In the present paper, we proposed a methodology for deriving scientifically based exposure limit values for transportation noise exposure in order to review and update noise limits in the Swiss legislation. In contrast to the previously adopted method of setting limit values, which was (almost) exclusively based on annoyance surveys, we also took into account somatic disease effects of noise, that are described in epidemiological studies. The procedure of deriving a limit value on the basis of a comparison between "self-reported" effects and "somatic disease" effects that are explicitly considered equally health-relevant, combined with the arithmetic averaging of previously determined endpoint-related threshold levels, as seen in Sections 2.4 and 2.5, is without precedents. Thus, it was not possible to rely on previous experience with this "heuristic".

In the course of the work, we found that the application of one and the same acceptable risk criterion to the

exposure-response relationships of different studies (possibly even concerning the same endpoint) would result in very different limit values, which ultimately means that many studies seem to be essentially "in disagreement" about the relationship between exposure and effect. The simple averaging of the endpoint-related threshold levels within the respective effect category – as carried out in Step 5 – may be rather risky with such heterogeneous results. Calculating an average value, however, is the simplest possible method of dealing with unknown uncertainties in individual studies while keeping all the evidence deemed sound enough to back exposure limit values in the game. Thus, our approach was in line with the intention of the Federal Noise Abatement Commission to substantiate the proposed limit values empirically as broadly as possible, i.e. to actually use all available evidence considered to be of sufficient quality. Finally, it is not unusual for noise effect studies that their results often differ quite considerably. For example, because they are not readily comparable with each other in terms of the reliability of the noise exposure data they use, or because their results were obtained at different times, with different methods, in different cultures, etc. Of course, it would be more desirable if the consensus between individual studies were greater or the heterogeneity of study results in meta-analyses smaller.

The most difficult decisions we had to take concerned the definition of the acceptable risks. Although such arbitrary settings are not science-based, they were inevitable, because without them it would be impossible to derive concrete limit values at all. In any case, we tried to limit arbitrary decisions in this process to the necessary minimum.

## ACKNOWLEDGEMENTS

## 4. REFERENCES

[1] WHO, "Environmental Noise Guidelines for the European Region," 2018.

[2] F. Manuele, "Acceptable Risk: Time for SH&E Professionals to Adopt the Concept," *Professional safety,* vol. 55, pp. 30-38, 2010.

[3] T. Jung, H. Jahraus, and W. Burkart, "Akzeptables Risiko als Basis für gesetzliche Regelungen im Umweltschutz," *Bundesgesundheitsblatt – Gesundheitsforschung – Gesundheitsschutz,* vol. 5, pp. 328-335, 2000.

[4] M. Brink, B. Schäffer, D. Vienneau, M. Foraster, R. Pieren, I. C. Eze, C. Cajochen, N. Probst-Hensch, M. Röösli, and J.-M. Wunderli, "A survey on exposure-response relationships for road, rail, and aircraft noise annoyance: Differences between continuous and intermittent noise," *Environment International,* vol. 125, pp. 277-290, 2019/04/01/ 2019.

[5] R. Guski, D. Schreckenberg, and R. Schuemer, "WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Annoyance," *International Journal of Environmental Research and Public Health,* vol. 14, p. 1539, 2017.

[6] D. Vienneau, A. Saucy, B. Schäffer, L. Tangermann, J. M. Wunderli, and M. Röösli, "Transportation noise exposure and cardiovascular mortality: a 15-year analysis in Switzerland," in *ISEE 2020* Washington DC, 2020.

[7] D. Vienneau, I. Eze, N. Probst-Hensch, and M. Röösli, "Association Between Transportation Noise and Cardiometabolic Diseases: an Update of the WHO Meta-analysis," in *ICA 2019* Aachen, 2019.

[8] E. van Kempen, M. Casas, G. Pershagen, and M. Foraster, "WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Cardiovascular and Metabolic Effects: A Summary," *Int J Environ Res Public Health,* vol. 15, Feb 22 2018.

[9] M. Basner and S. McGuire, "WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep," *International Journal of Environmental Research and Public Health,* vol. 15, p. 519, 2018.

[10] M. Brink, B. Schäffer, D. Vienneau, R. Pieren, M. Foraster, I. C. Eze, F. Rudzik, L. Thiesse, C. Cajochen, N. Probst-Hensch, M. Röösli, and J. M. Wunderli, "Self-Reported Sleep Disturbance from Road, Rail and Aircraft Noise: Exposure-Response Relationships and Effect Modifiers in the SiRENE Study," *International Journal of Environmental Research and Public Health,* vol. 16, p. 4186, 2019.

[11] H. Heritier, D. Vienneau, M. Foraster, I. C. Eze, E. Schaffner, L. Thiesse, F. Rudzik, M. Habermacher, M. Kopfli, R. Pieren, M. Brink, C. Cajochen, J. M. Wunderli, N. Probst-Hensch, M. Roosli, and S. N. C. s. group, "Transportation noise exposure and cardiovascular mortality: a nationwide cohort study from Switzerland," *Eur J Epidemiol,* vol. 32, pp. 307–315, Mar 09 2017.