Limit values for military shooting noise

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Abstract
Noise abatement in Switzerland is ruled by the principle that noise exposure should be reduced to the extent that it is feasible from a technical and functional viewpoint and financially tolerable and that the well-being of the affected population is not seriously impaired. The latter protection criterion of preserving the population's well-being is the basis for deriving exposure limit values such as Impact Thresholds, Planning Values and Alarm Values. There are already limit values set for most current noise sources such as roads, railways and airports. Still to be specified are the limit values for noise emitted from military training grounds with small and large calibre shooting activities. In a survey, more than 1000 residents in the neighbourhood of eight major military shooting ranges of Switzerland were interviewed in order to determine the degree of annoyance. The results of the questionnaire allowed to establish an exposure-effect relationship and to propose an assessment method with limit values. The first estimates show that there are approximately twenty thousand people exposed to noise levels above Impact Thresholds. Following the legislation process the limit values will trigger a fifteen year action plan to monitor and reduce noise exposure of the population.

Keywords: military shooting noise, limit values

1 Introduction

In the last decades noise as a public health issue has become of growing concern in the European Union. Although noise is not a fundamental threat to human existence like climate change or water pollution, it is one of the most dominant environmental nuisance. Starting with the Green Paper of noise abatement [1] in the mid nineties the EU has since then undertaken remarkable efforts for developing regulations to stop the still growing noise
exposure. With the adoption of the Environmental Noise Directive (END) in 2002 the EU set the basis for establishing noise maps and noise abatement action plans that should reverse the tendency of growing community noise exposure. The END focus on the most dominant traffic noise sources such as roads, railway lines and airports as well as industrial sites. Other noise sources such as e.g. military or civil shooting grounds are not covered, and there is no generally agreed regulation or computation method to determine noise exposure. Another particularity of the END is the absence of limit values, which are necessary to trigger remediation measures. The EU has left this task to the member states, knowing that a general agreement would be very difficult to achieve.

2 Noise abatement in Switzerland

Compared to the EU, Switzerland is a pioneer in noise abatement. The first steps started in the early sixties with parliamentary activities to initiate remedies against the more and more increasing noise exposure and its negative effects on public health. In the following years an environmental protection agency was funded and the Environmental Protection Law [1] entered into force in 1985. Therein was included the noise abatement policy, which was further elaborated in detail in the Noise Abatement Ordinance [2] in 1987. The policy [3] can be split up into three elements: Assessment, Enforcement and Controlling.

The Assessment deals with determining the relevant health effects and its optimal acoustic exposure indicator. From exposure and health effects, exposure-effect relationships should be derived, which form the basis for setting critical levels or limit values according to a specific health criterion. Once the critical levels established it is possible to calculate the critical noise exposure and its health impact on the population as well as to enforce noise abatement action plans.

The principles of enforcement are noise reduction at source, cooperation of all stakeholders to find efficient and acceptable solutions, polluter-pays, remediation of existing noisy installations and noise prevention by emission control of new installations and vehicles as well as adequate spatial planning procedures. Unlike the EU, the Swiss policy fixed limit values for the most dominant noise sources at a very early stage. Therefore, the legal basis contains already limit values for roads, railways, industry and trade installations, civil and military airports as well as civil shooting ranges. Still to be specified are limit values for military training grounds with small and large calibre shooting activities. The enforcement of the action plan (Fig. 2) started in 1987 and is bound to finish latest by 2020 for those noise sources whose limit values have already been established.

Controlling consists of monitoring not only state indicators such as noise exposure but also drivers (traffic, shooting activities), impacts (health effects, costs) and responses (action plans and their efficiency). Conclusions based on the monitoring results should lead to modifications of action plans or even the legal basis if necessary. In 2002 a first controlling report of noise abatement in Switzerland [3] was published and in 2009 there was a further step in integrating all the necessary data (e.g. geographical information, traffic activities) in a database (SonBÂSE) that will serve as the controlling instrument for noise abatement in Switzerland [4]. The following descriptions focus on the assessment method with the aim to establish limit values for military shooting grounds.
3 Military shooting noise

Compared to noise from traffic infrastructures, military shooting grounds are not a dominant source of noise in Switzerland, even though gun shots from light and heavy weapons can frequently be heard in the narrow mountain valleys. With a population of 7.5 million inhabitants and an area of 41'000 km² there are about 200'000 soldiers who serve in the army. They carry out their services on a regular basis on over 350 army installations and shooting grounds distributed all over the country (Fig. 3).

Figure 2 – Action plan of noise abatement in Switzerland.

Figure 3 – Military shooting grounds
The majority of these grounds are very small with yearly activities limited to a few days. Most of the shooting takes place in about a dozen grounds containing small infantry shooting ranges as well as expanded artillery and tank training facilities. There are about 25 million small calibre shoots every year from military activities. It must also be mentioned that there is a remarkable civil shooting activity in Switzerland with the number of shots being about three times higher than those from military shooting. The number of large calibre shoots (bigger than 50mm) per year is approximately 120'000. The four loudest weapons used are the Leopard II tank, the howitzer M109, the Haglund CV90 and the assault rifle 90 (Fig. 4).

![Assault rifle 90](image1)
![Haglund CV90](image2)
![Howitzer M109](image3)
![Leopard II](image4)

Figure 4 – Weapons used on military shooting grounds

4 Establishing noise exposure limit values

The assessment method to establish limit values consists of four steps:
- identifying the relevant health effects (also called hazard identification)
- defining an optimal noise exposure indicator
- deriving the exposure-effect relationship
- setting limit values according to a specific health criterion

4.1 Relevant health effects

There are various health effects from noise exposure and it would be very difficult to establish limit values for all of them. However, it is generally assumed that avoiding short term effects, such as hearing impairment, interference with speech communication, sleep disturbance and annoyance, prevents most long term effects, e.g. the development of cardiovascular diseases.

In case of military shooting noise the danger of hearing impairment from loud blasts of light and heavy gun fire and explosions should be prevented by equipping the personnel with good hearing protection devices. With regard to the population it is also assumed that their settlements are always far away enough not to be exposed to sound pressure levels that
could cause immediate damage to the ears. Most military training takes place during daytime or to a very limited extent in the early evening hours. The occurrences of sleep disturbance can therefore be virtually excluded. It was therefore concluded that the relevant health effect of military shooting noise is annoyance and that other effects are irrelevant if annoyance can be avoided.

The study to assess annoyance of military shooting noise exposure was carried out between September and November 2007. Bearing in mind that by directly asking people about their perception of military noise exposure and annoyance could bias the responses, we developed a questionnaire that assessed various criteria of living quality. The survey included some 1000 persons in different communities who live in the neighbourhood of the eight most important military shooting grounds. Each interview took about 15 to 20 minutes and was carried out by means of a computer aided telephone interview system at a market research bureau.

The sampling procedure to assess annoyance is generally carried out by using a linear scale on which subjects can indicate their degree of annoyance. In the early studies of noise annoyances in Switzerland a numerical 11-point scale was used. For this study we assessed the degree of annoyance also with the verbal 5-point scale following the ICBEN suggestion [5]. A detailed description of the survey study and its evaluation can be found in [6,7,8].

4.2 Exposure indicator

In order to have a Switzerland-wide sampling basis the survey was carried out around the eight most important shooting grounds. The input data for noise exposure like weapon types and ammunitions, the corresponding number of shots and position as well as shooting days and time distribution of the activity between day and evening were collected. From this data rough noise exposure maps were calculated in order to select with the help of data from the last census the addresses of possible subjects to be interviewed. The exact noise exposure was calculated after the interviews for those subjects who responded to the questionnaire, taking into account meteorological conditions and topological ground damping effects.

Most descriptors of noise exposure are based on the total sound energy distributed over a certain time. These equivalent energy indicators (Leq) are sometimes complemented with corrections (penalties), yielding a rating level Lr that better predicts the health effect in question. In Switzerland the Lr is used for most noise sources such as traffic and industry infrastructures. On the other hand, the basis for the indicator for civil shooting ranges of light guns is a compound measure derived from the number of shots and shooting days and the A-weighted maximum sound level with the FAST time constant. This indicator, however, was not applicable for military shooting grounds, where a variety of different weapons, such as heavy guns from Leopard II tanks and M109 howitzer and Haglund CV90 armoured personnel carriers as well as light guns like the Swiss assault rifle 90 are used.

The best indicator was found by optimizing the exposure-effect relationship by maximizing the explained variance from acoustic exposure. Several indicators like L_{AE} and L_{CE} as well as compounds of day- and night-indicators were evaluated. It was found that L_{AE} integrated over one year was basically the optimum indicator, although a composition similar to the L_{den} will finally be selected in order to "penalize" shooting activities during the evening hours and the weekends with a 5dB penalty. This penalty only slightly increased the quality of the acoustic predictor. However, it is supposed to increase its acceptance in the population, taking into account the higher noise-sensitivity during evenings and weekends. Moreover, it is an incentive to minimize shooting during noise sensitive periods.
4.3 Exposure-effect relationship

Exposure-annoyance relationships were modelled by means of a logistic regression analysis for the dependent variable "Highly Annoyed", reflecting the proportion of the population highly annoyed by military shooting noise. As mentioned, there were two annoyance scales used in the questionnaire, a numerical 11-point scale and a verbal 5-point scale.

In accordance with the international standards [9], responses on the 11-point scale were considered as "highly annoyed" if they were in the range of 8, 9 or 10. For the verbal 5-point scale with the marks "not at all", "slightly", "moderately", "very" and "extremely" the two upper marks were taken as equivalent to "highly annoyed". Furthermore, the marks of the verbal scale had to be translated for the interviews into the Swiss languages, Swiss German and Italian. The French version was copied from Fields et al. [5].

Results of the exposure-annoyance relationship (Fig.5) show a typical increase in annoyance with increasing noise exposure. There is also a remarkable difference in the results between the two scales leading to a steeper logistic curve from the use of the verbal 5-point scale compared to the numerical 11-point scale. This could be partly explained by the difference in the cut-off point for "Highly Annoyed", being 60% with the 5-point scale and 72% with the 11-point scale. In other studies [10] congruent curves could be attained by statistically raising the cut-off point of the 5-point scale to 72% by weighting the response category "very" as proposed by Miedema and Vos [11]. This attempt, however, was not successful with the current data and so far no arguments have been found that could conclusively explain the differences in the exposure-annoyance relationships. Further studies will therefore be necessary to clarify this aspect.

Both sampling methods (numerical 11-point scale and verbal 5-point scale) were however considered scientifically correct and there was no convincing evidence to favour the result of
one method over the other. It was therefore concluded that the results from both methods represent the uncertainty of the applied sampling procedures and that both results should be taken into account for the exposure-annoyance relationship and for the setting of limit values.

4.4 Limit values

The noise abatement regulation in Switzerland specifies three types of exposure limit values. Each value is defined for four sensitivity levels that account for the noise sensitivity of the building zones.

- **Impact Thresholds (IT)** are to ensure that noise below these levels does not seriously disturb the well-being of the population;
- **Planning Values (PV)** concretize the prevention principle and are usually about 5dB lower than the Impact Thresholds;
- **Alarm Values (AV)** indicate the urgency for remediation measures and are usually about 10dB higher than the Impact Thresholds.

Sensitivity levels are defined in the following zones:

- **sensitivity level I** in zones with higher noise abatement requirements, notably in leisure zones;
- **sensitivity level II** in zones in which operations that emit noise are not permitted, notably in residential zones and zones for public buildings and installations;
- **sensitivity level III** in zones in which operations emitting a certain level of noise are permitted, notably in residential and industrial zones (mixed zones) and agricultural zones;
- **sensitivity level IV** in zones in which operations emitting a high level of noise are permitted, notably in industrial zones.

In accordance with the Environmental Protection Law, Impact Thresholds should be set so that, in the light of scientific knowledge and experience, noise exposure below these thresholds will not seriously disturb the well-being of the population. It is generally accepted that this health criterion is fulfilled if the Impact Threshold of sensitivity level II (residential zones) is set where about 25% of the population is highly annoyed (HA) by the noise exposure in question.

As explained in the former chapter, it was agreed that both curves from the 11- and the 5-point scale should be used as basis for the setting of the Impact Threshold (Fig. 5). The Impact Threshold (25% HA) should therefore be somewhere between 110dB and 118dB (L_{Ae}). As a compromise one could set the Impact Threshold in the middle of both values (114dB), but in order to follow the precautionary principle it was decided to set it at 113dB. The other values were set by reducing or increasing the levels by 5 or 10 dB according to the sensitivity levels and the type of the exposure limit as shown in Figure 6. More information on the procedures of setting limit values for military shooting noise can be found in [12].

The legal process to include the scientific proposal into the Swiss Noise Abatement Ordinance [2] started in February 2010 with official consultations of the concerned cantons (regional states), organisations and interest groups. It is planned to finish legislation by mid 2010 so that the exposure limit values for military shooting ranges can be enforced with a noise remediation action plan that will last up to 2025.
### 5 Consequences of noise exposure

First estimates show that there are about 20'000 people exposed to military shooting noise above the new Impact Thresholds. Apart from impacts on life quality and public health, noise exposure also has consequences on the noisy installations and on spatial planning.

On the side of the noise emitter there are regulations to reduce emissions to the extent that it is feasible from a technical and functional viewpoint and financially tolerable and that the well-being of the affected population is not seriously impaired. Furthermore, installations have to respect the relevant limit values according to the type of installation (Fig. 7).

![Diagram](image_url)

**Figure 6 – Method for setting limit values based on the Impact Threshold of residential zones**

<table>
<thead>
<tr>
<th>Sensitivity levels</th>
<th>Planning Value</th>
<th>Impact Threshold</th>
<th>Alarm Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resort zones</td>
<td>x-10</td>
<td>X-5</td>
<td>x+5</td>
</tr>
<tr>
<td>Residential zones</td>
<td>x-5</td>
<td>X</td>
<td>x+10</td>
</tr>
<tr>
<td>Mixed zones</td>
<td>x</td>
<td>X+5</td>
<td>x+10</td>
</tr>
<tr>
<td>Industrial zones</td>
<td>x+5</td>
<td>X+10</td>
<td>x+15</td>
</tr>
</tbody>
</table>

**Figure 7 – Consequences of noise exposure from military shooting grounds.**
New military installations (built after 1.1.1985) must respect Planning Values while old installations (built before 1.1.1985) only have to respect Impact Thresholds. The interest of the military activity can, however, be considered more important than the noise protection of the population and in these cases the noisy installations are granted relaxations in respecting limit values. As compensation noise protection windows must be installed in houses of the exposed population. For noise of military shooting grounds, the total costs for remediation measures and noise protection windows are estimated to be in the range of a few dozens of million Euros.

On the side of the noise exposed there are precautionary regulations for spatial planning. Planning Values must be respected to designate or develop residential building zones and the construction of houses should only be permitted if noise exposure is below Impact Thresholds. Legal exceptions for development and construction are possible for small parts of building zones and in case of overriding public interest, respectively.

![Diagram](image.png)

Figure 8 – Consequences of noise exposure on spatial planning.

6 Conclusions

Exposure limit values for military shooting noise in Switzerland are based on the exposure-annoyance relationship derived from a survey of about 1000 people living around eight military shooting grounds. The available data is sufficient to specify exposure limit values, which are bound to be legally established by mid 2010. First estimates show that there are about 20'000 people exposed to noise above the new Impact Thresholds. Limit values are the prerequisite to trigger the enforcement of a 15 year action plan to reduce noise exposure on the population.

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References


