New Swiss legislation to protect persons from vibrations and structure-borne noise

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An ordinance has been drafted which protects persons in buildings against the harmful effects or nuisance of vibration and structure-borne noise such as from railways. The ordinance will enter into force soon. The legislation is based on the classical principle of an evaluative determination with subsequent rating on the basis of exposure limits. The vibration exposure limits are orientated on the basis of the perception threshold. For structure-borne noise, the exposure limits are described by energy-equivalent units and are stipulated for an audible range distinctly above threshold. Furthermore, maximum levels are also applied at night so as to take sleep disturbance into account. Aspects such as proportionality and stipulated remediation deadlines facilitate implementation of the legislation. However, remediation is problematic in relation to rail transport facilities in particular. This is due to the high complexity of implementation measures and the related costs. The technical developments demanded in the ordinance should make a beneficial contribution to realising the long-term goals.

1. THE CURRENT SITUATION

The Swiss Environmental Protection Act (EPA) is intended to protect people, animals and plants, their biological communities and habitats against harmful effects or nuisances (EPA 1985). The effects also include vibration caused by the construction or operation of installations. Figure 1 shows a typical exposure situation. As outlined below, structure-borne noise also has to be taken into account when considering the impact of vibration. For noise impact, the Noise Abatement Ordinance (NAO 1987) entered into force 2 years after the EPA. To date, there is no analogous ordinance for vibration.

This is probably due to the complexity of the subject, beginning from the description of propagation, immission, perception and sensation to the implementation of measures. Moreover, far fewer people are affected by vibration than by noise. At present in Switzerland there are currently 40,000 people affected by excessive vibration as defined by the EPA. Of this some 30,000 are affected by vibration due to railways. Industrial and commercial installations represent the second most important source. These are followed by construction sites, roads and blasting operations. In comparison with vibration, in the case of noise some 1,350,000 people are seriously affected as defined by the EPA.

Because there are no precise evaluation procedures with regard to the effect of vibration on people, the EPA has to date been executed on the basis of further domestic and foreign regulations. For rail traffic installations the "Directive on the Evaluation of Vibration and Structure-borne Noise of Rail Traffic Installations" has been applied (1999). In this directive, with regard to vibration itself, reference is made to DIN 4150-2 "Vibrations in buildings - Part 2: Effects on persons in buildings" (DIN4150 1999). This directive will be replaced by a Vibration Abatement Ordinance which applies to all types of installations which generate vibration.

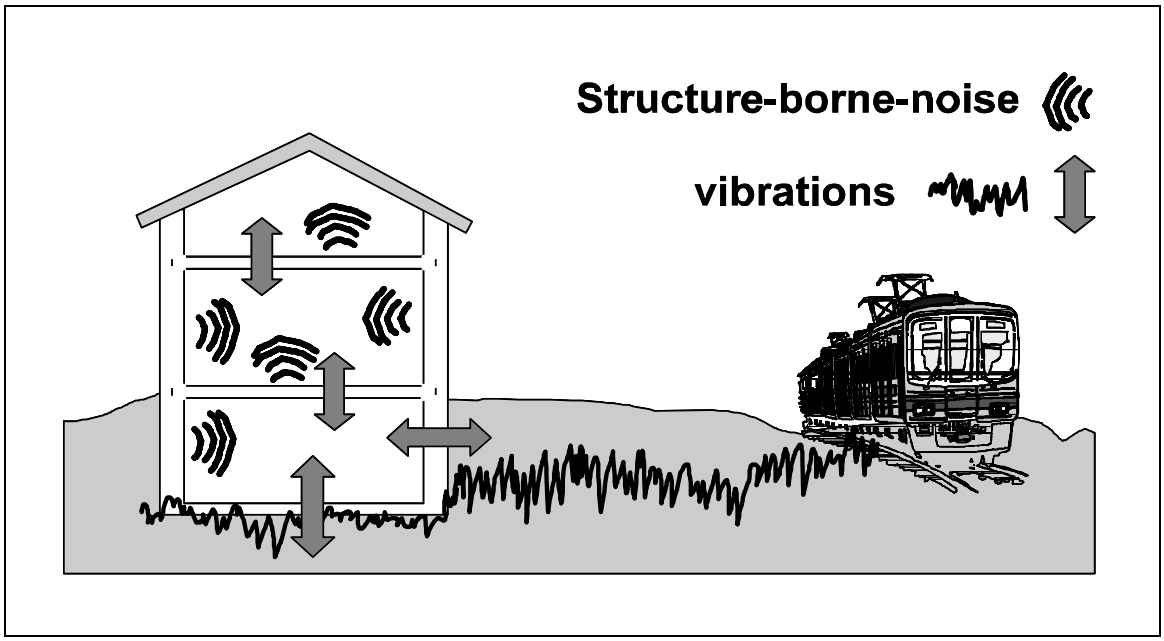

Figure 1. Typical exposure situation

Vibrations from a source – a railway, for example – are transmitted through the ground to a building, which vibrates as a result. The propagation of the oscillations in the building is determined primarily by the dynamic characteristics of the building and the type of oscillations. These oscillations are often more intense on the upper floors. People inside the building perceive them on the one hand through physical contact with the shell of the building and on the other hand through hearing. When the building structure transmits the oscillations to the ambient medium, the air, structure-borne noise is produced.

2. EFFECTS ON PEOPLE

The legislation is primarily intended to protect people residing inside buildings.

2.1. VIBRATIONS

Inside buildings, vibrations are generally felt throughout the whole body. There is no distinctive vibration-sensitive organ. Perception takes place along receptors in the skin and muscles. It is the biomechanical vibration behaviour of individual parts of the body (including resonance phenomena) which essentially determine perception. It should also be remembered that mechanical vibration can cause annoyance, incapacity, reduced performance or damage to health (Dupuis 1989). Annoying and disturbing vibration sometimes result in sensitivities analogous to those generated by noise. According to the World Health Organisation (WHO), annoyance and disturbance due to vibration are deemed to be injurious to health, as health is defined not merely as the absence of disease but as physical, mental and social well-being.

Various authors state that human beings have no range of tolerance in relation to vibration (Zeichart 1993): "Barely perceived, it is disturbing!" Vibration "shakes" people in the truest sense of the word; it gets under one's skin and causes the entire body to vibrate. It is a so-called "proximal stimulus" which is often perceived as a menace. Surveys support the requirement for an evaluation which is based on the perception threshold. Like the sensitivity to noise, the sensitivity to vibration is prone to large subjective variations. Furthermore, the

biomechanical reaction – which is also subjective and prone to situational variance which is more pronounced than with the perception of sound – makes precise evaluation more difficult.

2.2. STRUCTURE-BORNE NOISE

Structure-borne noise, like noise in general, is generally perceived by the sense of hearing. Due to its low frequencies (a dull rumbling), structure-borne noise requires special consideration in order to achieve an evaluation which is effect-orientated (Krahé 2008). Surveys in the low-frequency and infrasound range indicate auditory perception down to 2 Hz (M*f* ller 1984). A marked increase in isophones below 40 Hz can be observed. In addition, for low frequencies the audible dynamic is reduced to such an extent that even the smallest differences in sound level are perceived as major differences in subjective loudness and therefore also in the perception of the sound. At night, sleep disturbance is a phenomenon which is mainly manifested as a waking reaction.

2.3. COMPARISON AND COMBINATION EFFECT

Noise, vibration and structure-borne noise are perceived by hearing or by the whole body, as shown in Table I. With regard to sensitivity (evaluated perception), people experience unpleasantness and disturbance in all three cases. In the case of noise, the source may additionally be located outside (non-proximal stimulus). There is also the possibility of finding quietness in a room away from the noise or simply by closing the window. The situation is different in the case of vibration and structure-borne noise. These are proximal stimuli: the vibration literally gets under one's skin; it is like sitting inside a loudspeaker. There is no possibility of escape: one is simply at the mercy of the phenomenon. In addition, the inability to precisely locate the problem gives rise to a feeling of menace. Sensitivity to structure-borne noise is more closely related to vibration than to noise. The impact in relation to human sensitivity should be evaluated in regulations. It is therefore appropriate to consider vibration and structure-borne noise as two aspects of one modality.

These observations lead to the following model: a human being experiences the vibrating room on the one hand via the contact surfaces of the body with the room and on the other via the structure-borne noise, through the

Table 1. Comparison of perception of, and sensitivity to, noise, vibration and structure-borne noise

Impact	Human being	
	Perception	Sensation
Noise	Ear	Disturbance and annoyance
		As a non-proximal stimulus escape possible localisation possible
Vibration	In a tactile manner by the body	Disturbance and annoyance
		As a proximal stimulus no escape possible no localisation possible
Structure-borne noise	In an auditory manner by the ear	Disturbance and annoyance
		As a proximal stimulus no escape possible no localisation possible

sense of hearing. These two perceptions are the two aspects of vibration in a more general sense.

Essentially there are two impacts. However, in practice the relationship between the impacts may be such that only one modality is experienced. The issue of the interaction of noise and vibration is manifold. One reliable statement – which Howarth and Griffin (Howarth 1989) refer to, among other things – is that the mean and intra-individual standard deviations of the experience for combined exposure are elevated. Therefore in practice people subjected to the stimulus are often unable to decide whether they are hearing something or feeling it. In this context, it is necessary to refer to the source-related airborne sound, which enters through closed or open windows. The overall perception or sensation is occasionally also accompanied by indirect noise-effects, such as the rattling of glasses due to vibration.

3. PROTECTION GOALS AND PROTECTION CONCEPT

3.1. PROTECTION GOALS

The EPA requires that the population's well-being is not substantially adversely affected by either vibration or noise. The degree of unpleasantness is therefore implicit. It is determined on the basis of the state of the science or on the basis of experience. Harmful vibration – in the workplace, for example – is controlled by other Acts. As mentioned in section 2.2, the actual vibration causes annoyance and disturbance right from the threshold of perception. Unlike with noise, there is no tolerance range. The evaluation is therefore determined on the basis of the perception threshold. A K-value of 0.1 (see section 4.6) gives an example for the immission limit of residential zones. This value is comparable with that of DIN 4150-2 (DIN4150 1999).

Protection from structure-borne noise is based on experience gained evaluating low-frequency sound. A maximum criterion is incorporated for night-time evaluation. An example of the evaluation of purely residential zones at night is that 30 dB(A) is used for the energy-equivalent permanent sound level in the loudest hour and 48 dB(A) is used for the 90% quantile of the maximum value of all events. The maximum value criterion applies only to roads and railways.

3.2. PROTECTION CONCEPT

The legislation is based on the classical principle of an evaluative determination with subsequent rating on the basis of exposure limits. The legislation includes aspects of proportionality such as long-term remediation deadlines.

In terms of the concept, regulation of vibration is based on concretising the EPA: vibration and structure-borne noise must be limited using measures at source. According to the two-stage protection concept (see figure 2) of immission protection, emissions must be limited independently of the existing environmental impact within the framework of precautionary measures (1st stage) and as far as technically and operationally possible and economically reasonable.

Emissions are limited more strictly (2nd stage) if the effects are found or expected to be harmful or a nuisance, taking into account the existing level of environmental pollution. The Federal Council stipulates in an ordinance the immission limits for assessing harmful effects or nuisances. The immission limits for structure-borne noise and for noise and vibration must be set so that, in the light of current scientific knowledge and experience, immissions below these levels will not seriously adversely affect the well-being of the population. Separate limit value schemes are established both for vibration and structure-borne noise. Both are based on vibration values.

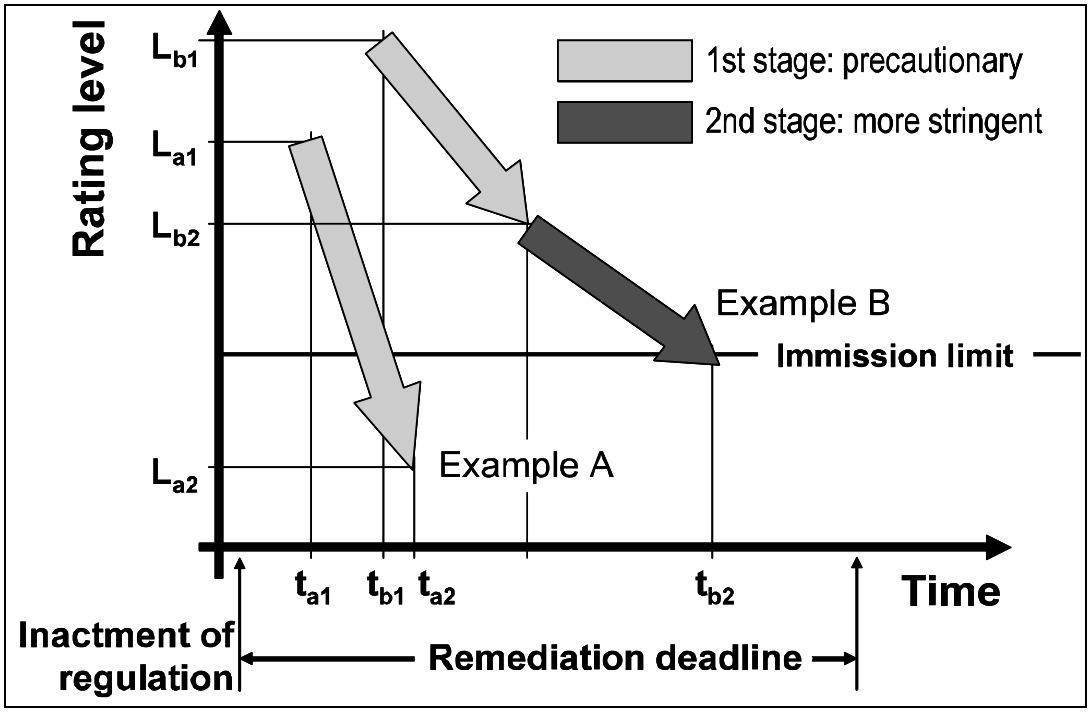

Figure 2. Two-stage protection concept. Example A: level reduction from L_{a1} to L_{a2} in the period from t_{a1} to t_{a2} (precaution sufficient). Example B: Level reduction from $_{Lb1}$ to L_{b2} within the framework of precautionary measures and with more stringent measures to below the immission limit.

Existing installations which do not meet the legal requirements must undergo remediation. The Federal Council issues regulations concerning the installations, the scope of the measures to be taken, the deadlines and the procedures to be applied. The immission limits for vibration must not be exceeded, even if the remediation is disproportionate in individual cases. The legislator has already decided on proportionality and no longer gives the authorities any leeway with regard to special consideration of interests in individual cases.

The special case of rail traffic installations: The principle applies that all existing permanent installations are subject to the remediation obligation. Railway installations (standard-gauge railways, trams) are also included in this legislation. In the case of remediation of railway installations, however, under considerations related to proportionality, account must be taken of the specific technical and operational possibilities and the financial cost. Primarily, this should be achieved by granting longer remediation deadlines and the consistent implementation of simultaneous remediation during conversion and extension work.

Moreover, in terms of immissions in relation to all installations, appropriate structural protection from vibration must be provided (so-called minimum structural protection) when buildings are constructed.

According to the EPA, anyone causing vibration must bear the costs.

4. THE LEGISLATION

In this chapter the fundamental characteristics of the legislation will be summarized.

4.1. PURPOSE AND SCOPE

The ordinance is intended to protect the population from harmful or annoying vibration. It therefore regulates the limitation of vibration generated in

vibration-sensitive rooms during construction and operation. Vibration-sensitive rooms are defined as rooms in buildings that are regularly occupied by persons for longer periods (cp. Art. 2 NAO). In this regard it regulates determination and evaluation by means of immission limits. In addition, the minimum structural protection from vibration is stipulated in the case of new buildings with vibration-sensitive rooms. Protection from vibration in industrial areas or in military structures and installations is excluded from the legislation.

4.2. EQUIPMENT, MACHINERY AND VEHICLES

In principle, the 2-stage protection concept applies (see section 3.2). Vibration emissions from vehicles, vessels, and aircraft as well as equipment and machinery which are permanently connected to stationary installations are limited in accordance with the regulation concerning the stationary installations to which they are associated or the operation for which they serve.

Separate recommendations are issued for construction sites.

4.3. NEW STATIONARY INSTALLATIONS

The two-stage protection concept of emission limitation also applies to new stationary installations. Owners of installations must pay the costs and the enforcement authorities evaluate the effectiveness of the measures. The terms “new” and “existing” installations are separated by the time at which the legislation enters into force.

4.4. EXISTING STATIONARY INSTALLATIONS

The following applies in general: If the immission limits are exceeded by existing stationary installations, those must be remedied to the extent that this is technically and operationally possible and it is economically reasonable. The measures are sufficiently stringent to ensure that the immission limits are met. The remediation work must be completed within 20 years at the latest. Owners must bear the costs of remediation. The enforcement authorities evaluate the remediation measures and the Confederation periodically surveys the status of remediation work.

Special regulations for existing railway installations: sections of existing railway installations that contribute significantly to the impact thresholds being exceeded shall be improved in such a way that the immission limits are met. Remediation must be performed as far as proportionate with respect to the state of the art and there is no conflict with overriding interests, in particular operational safety. Sections where the superstructure is being renovated must undergo remediation at the same time. Remediation must be concluded within 35 years at the latest of the entry into force of this ordinance.

4.5. MINIMUM PROTECTION FROM VIBRATION FOR NEW BUILDINGS

New buildings with rooms which are sensitive to vibration may be built only if the building complies with the accepted rules for construction relating to protection from vibration. If the immission limits are exceeded in a new building, the enforcement authority will increase the requirements for structural protection from vibration accordingly; the increase depends on the extent to which the immission limits have been exceeded.

For buildings which have not yet been constructed, the dynamic behaviour of the building will be taken into consideration using the transmission factor. The transmission factor is the relationship between the amplitude of the vertical vibration signal at the point of measurement and

that at the foundation of the building or in the free field on the ground. Above 10 Hz, the transmission factor must generally not exceed 20, and below 10 Hz must not exceed 10. In the case of more stringent requirements, the transmission factor above 10 Hz must not exceed 7.5 and below 10 Hz the maximum value is 2.5. For buildings which have not yet been constructed, a reduction in transmission of vibration from the free field into the building may be taken into account.

4.6. DETERMINATION

The vibration signal is determined as a velocity in mm/s using measurements or calculations. Apart from velocity the rating level is calculated – containing also a band-limitation (1 to 80 Hz) and a frequency weighting (cp. Griffin 1996) - as a K-value without dimensions. This K-value is essentially an energy-equivalent value, obtained from the vibration maximum values within 15 second periods. The needs of the population in relation to recreation are taken into account. In rooms which are sensitive to vibration, the vibration is generally determined in the middle of the floor. In the case of non built-up plots in developed building zones the vibration is determined where rooms sensitive to vibration may be built (according to building and planning law) and where the maximum vibration can be expected. The determination for these rooms is based on buildings which meet the minimum protection requirements (section 4.5).

The rating level for structure-borne noise is also calculated on the basis of the vibration signal. The rating level for structure-borne noise, however, may also be based on the measured noise if no disturbing noise is present. Another reason for direct determination via noise measurements is the effect of the special specific dynamic characteristics of the vibration-sensitive rooms. In this case calculation would not produce an evaluation corresponding to the disturbance. The rating level for structure-borne noise is an energy-equivalent value. In the daytime, it relates to 16 hours. For night-time evaluation, a value is produced for each hour. In addition there is a maximum value, which essentially is an energy-equivalent value for a 5 second period. The structure-borne noise is determined where it is perceived by persons regularly and over extended periods.

4.7. EVALUATION

The enforcement authorities evaluate the determined vibration by using the immission limits. These apply in the rooms which are sensitive to vibration. The impact is evaluated differently for day and night according to sensitivity stages. Residential zones are the main focus of the evaluation. There, a K-value of 0.1 (immission limit) applies to daytime (06:00-22:00) vibration and 0.7 to night-time (22:00-06:00) vibration. For structure-borne noise, it is 40 dB(A) for the daytime (averaged value over 16 hours) and 30 dB(A) at night (for the loudest hour). Additionally a maximum value of 48 dB(A) applies at night for road transport and railway installations (considering the 90% quantile of the maximum value of all events).

4.8. PROMOTION OF MEASURES

The legislation requires authorities to monitor the state of the art and where applicable to support development.

5. CONCLUSIONS

The legislation as outlined above is between the drafting and enactment stage. It is therefore described only in terms of its principal characteristics. The intended protection of the new regulation can be compared with that in DIN 4150-2. Remediation is problematic, especially in the case of railway installations. The reason for this

is the high degree of complexity in implementing the measures and the associated costs which are high. The expensive and complex process of implementing remediation – particularly of the railways – will, however, be alleviated by aspects of proportionality, in particular by long remediation deadlines. Prior to the entry into force of the ordinance valuable measures against vibration and structure-borne noise are needed. Developments of those measures were progressing successfully. Sleeper pads are currently a very promising solution for railways. This measure – an insulating layer between the sleeper and the ballast – should considerably increase reduce emissions. Furthermore, promotion of technical development within the framework of the ordinance will have a favourable long-term effect on achieving the objectives. For vibrations and also for structure-borne noise, nowadays a common European regulation is not yet in sight.

REFERENCES

"Environmental Protection Act" EPA; SR 814.01, art. 1 para. 1, 1985
http://www.admin.ch/ch/d/sr/8/814.01.de.pdf

"Noise Abatement Ordinance", NAO, SR 814.41, 1987
http://www.admin.ch/ch/d/sr/8/814.41.de.pdf

"Weisung zur Beurteilung von Erschütterungen und Körperschall von Schienenverkehrsanlagen" (Directive on Evaluation of Vibration and Structure-Borne Noise from Rail Traffic Installations), 1999
http://www.bafu.admin.ch/publikationen/index.html?action=show_publ&lang=de&id_thema=17&series=VU&nr_publ=6003

"DIN 4150-2:1999-06" Vibrations in buildings - Part 2: Effects on persons in buildings, 1999

H Dupuis "Acute Effects of Mechanical Vibration" in: KONIETZKO, J.; DUPUIS, H. (Hrsg.): Handbuch der Arbeitsmedizin. Arbeitsphysiologie, Beanspruchung durch die Arbeitsumwelt, Kap. III-4.1. S. 1-11 ecomed Verl.Ges., Landsberg a.L. 1989

K Zeichart, A Sinz, R Schuemer und A Schuemer-Kohrs "Vibration Effects due to Rail Traffic" Report on an interdisciplinary research project on behalf of the Federal Environment Office (Berlin) and the Federal Railways Central Office (Munich), Munich, February 1993

D Krahé " Why can low-frequency noise be extraordinarily unpleasant?", Lärmbekämpfung, issue 2, 2008

H M*f*ller and J Andersen "Loudness of Pure Tones at Low and Infrasonic Frequencies" J. of Low Frequency Noise and Vib., Vol. 3, No. 2, pp. 78-87, 1984

H Howarth, M J Griffin "The relative importance of noise and vibration from railways" Applied Ergonomics, 1989

M J Griffin "Handbook of Human Vibration" Academic Press, cp. chapter 6.4, 1996

CITY OF SNOOZE

Club and bar owners have met Paris' mayor Bertrand Delanoe to try to find a way to breathe life back into the City of Lights. The push comes as a petition with 16,000 signatures called for a livelier nightlife in Paris, which it claimed was in danger of being overshadowed by London, Berlin and Madrid. "Paris risks becoming the European capital of sleep," it said, blaming overzealous regulators and residents who complained about noise from late-night venues