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How much protection do the sound insulation standards give and is this enough?

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ABSTRACT

Social surveys in several European countries have shown that inhabitants of multifamily dwellings are considerably annoyed by noise from their neighbour's activities. This is also in countries where sound insulation minimum requirements exist and have been enforced for many years. It is therefore necessary to establish data on the sound levels of activities in residential buildings and undertake survey comparisons with the responses by inhabitants. Such studies are also relevant to external noise break-in through facades from traffic noise which is related to actions plans according to END. From the data studies and surveys sound insulation requirements may be deduced. In some countries proposals have been developed on a correlation between sound insulation R'_w or $D_{nT,w}$ and percentage of people satisfied or annoyed, and classification schemes have been established with decreasing percentage of people annoyed, when applying higher sound classes. These schemes show great differences from country to country, and also the studies and questionnaire surveys have been developed in isolation from one another.

This paper will discuss the merits of having different sound insulation classes to meet different needs of activities and quietness in the home and to have verbal explanations of classes to make differences between classes understandable to ordinary people.

1. INTRODUCTION

Social surveys on the noise annoyance in dwellings caused by traffic noise intruding from outside or caused by noise from neighbour activities intruding through partitions and floors in multifamily houses have been carried out in several countries in the last decade or even before. Though these surveys have been based on different questionnaires asking about different details and defining different grades of annoyance (with different levels, different time of day, different activities), there is a uniform result, that a considerable percentage of people is annoyed by noise from the neighbours, even strongly or extremely annoyed.

An overview of the results of social surveys in some European countries has been compiled recently [1]. The neighbours' activities is the second most frequently mentioned noise source after road traffic, far more frequent than railways or air traffic. This finding should be seen together with the recommendation of the WHO LARES Survey about European housing [2] "Little attention was paid to neighbour noise till now and therefore pathological effects are considerably underestimated. The health effect of neighbour noise induced annoyance is approximately in the same range as the health effect of traffic noise induced annoyance. The results point out that it is necessary to improve the sound

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insulation in residential buildings. The cardio-respiratory system also reacts to neighbour noise with increased relative risks."

Due to inconsistent methodology, including different questionnaires, results from different countries are not easily comparable, and averaging seems impossible [1]. However, just to indicate the significance of the neighbour noise challenge, a rough estimate could be that more than 10% of European citizens are exposed to neighbour noise causing adverse effects on quality of life.

During the next years action plans according to the Environmental Noise Directive [3] (END) will be implemented, implying that traffic noise intruding from the outside could be considerably reduced. Consequently, neighbour noise may appear much louder than before, where it might have been masked by traffic noise. Thus, it can be expected that the percentage of people hearing their neighbours' activities and being annoyed by these will increase and that sound insulation in multifamily houses will get even more important.

2. EXISTING STANDARDS AND THE PROTECTION GIVEN

The considerable noise annoyance caused by neighbours' activities in multifamily houses is surprising, as in all the countries standards prescribing minimum sound insulation between adjacent dwellings have existed since the 1950es. Note: In this paper "standard" means a national document describing the regulatory building acoustic requirements. In most countries such requirements are defined in a standard, but in some countries they are found directly in the building regulations.

The requirements on airborne and impact sound insulation in existing standards have been compiled in detail [4,5] and show quite large differences. However, a correlation between required sound insulation in dwellings [4] on the one hand and percentage of annoyed inhabitants [1] on the other hand cannot be deduced as the data on percentage annoyed in the different countries have been established based on quite different questionnaires. Even with a uniform questionnaire, only a global view could be made, because requirements or enforcement may have changed over time. It is more relevant to know the correlation between the actual sound insulation and the satisfaction. Such research could provide information about the subjective and objective performance of specific building constructions and provide input for strategies for improving new and existing housing.

However, the question arises: How much protection against which noise is given or has to be given by the requirements in the standard? As the activities of people in their flats as well as the expected quietness are different, it will not be possible to make all activities inaudible or to protect the most noise sensitive persons. Also, of course, writing requirements in a standard does not in itself provide any protection against neighbour noise. In practice enforcement, acoustic expertise and workmanship play important roles.

In the Austrian standard ÖNORM B 8115-2 [6] e.g. is said: In this standard requirements and guidelines are laid down for the minimum sound insulation with the aim to protect *normally sensitive* persons against the transmission of *annoying* airborne and impact sound assuming *usual behaviour*." So there is insufficient protection for sensitive persons, insufficient protection against hearing neighbour noise in general (only annoying noise) and insufficient protection against noise from loud neighbours.

A similar statement is given in the Swiss standard SIA 181:2006 [7]. "The standard regulates the acoustic qualities of buildings and building components ……. It is expressly valid under the assumption of a *usual behaviour;* but it does not deal *inconsiderate* causing of noise and also not the *extraordinary sensitivity* of user". A very similar statement is also found in the German standard DIN 4109 [8].

In the Netherlands, class III (of five classes), which corresponds to the legal requirements, "gives protection against *unbearable disturbance* under *normal behaviour* of the occupants bearing in mind the neighbours" [9].

Considering the intentions of the regulatory requirements, cf. above quotes from standards, it becomes obvious that fulfilment of minimum sound insulation requirements in the standards does not ensure acoustical comfort.

Acoustical comfort can be characterized as follows:

- Absence of unwanted sound
- Desired sounds with the right level and quality
- Opportunities for activities without being heard by other people or annoying them

It is important to observe that acoustical comfort for a person is related to the person not only as a receiver of sound, but also as a source of sound. It can be annoying to be exposed to noise from neighbours, but it can be equally annoying to know that your activities disturb other people or can be heard, implying lack of privacy. Insufficient sound insulation between dwellings can also be a cause of neighbour conflicts.

3. SOUND LEVELS OF LIVING ACTIVITIES AND DESIRABLE QUIETNESS

A detailed comparison of sound levels of living activities and background noise levels in flats is shown in the following graphs and tables. The sound levels produced by living activities can be estimated by calculations according to ÖNORM S 5012 [10]. Examples are given in Table 1. The frequency content is assumed to be like pink noise (sound level equal in all third-octave bands) for conversation and for music.

Table 1: Sound levels of activities in living rooms

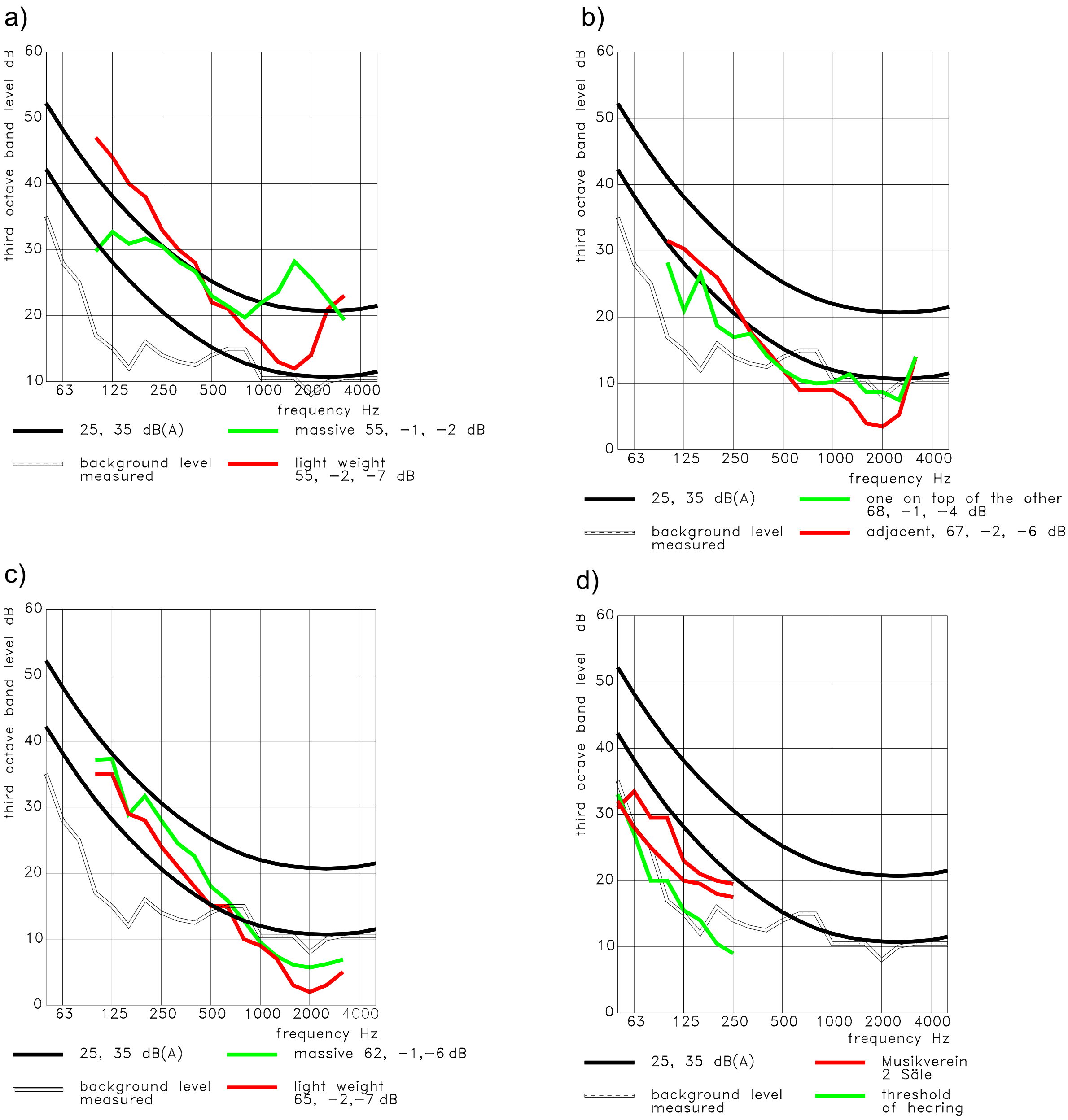
Room	Sound source	$L_{A,eq}$ (dB)	$L_{A,max}$ (dB)
75 m^3 living room with usual furnishing	Conversation with guests, 6 persons Talking with normal voice	73	82
	Lively conversation with laughter	78	87
	Music played at home 1 violin or similar instrument	78	86
100 m^3 living room with usual furnishing	Music played at home Ensemble with 6 instruments	91	98

For different sound levels in the source room and different degrees of sound insulation between the flats, the sound levels to be expected in the receiving room were calculated. It was found that a calculation result for the A-weighted sound level in the receiving room based on the A-weighted sound level in the source room and the weighted standardized sound level difference plus spectrum adaptation term C was equal to the result of the detailed calculation in third octave bands. Table 2 shows the A-weighted sound levels.

Table 2: A-weighted sound levels in source room and receiving room for different activities and for different sound insulation

A-weighted sound level in the source room (dB)	A-weighted sound level in the receiving room (dB) for sound insulation $D_{nT,w}$			
	55 dB	60 dB	65 dB	70 dB
73	19	14	9	4
78	24	19	14	9
86	32	27	22	17
91	37	32	27	22
98	44	39	34	29

In figure 1a-c the sound levels to be expected in the receiving room are represented for some examples of different sound insulation between adjacent flats ($D_{nT,w}$ = 55 dB corresponding to the minimum requirement in the Austrian standard and about $D_{nT,w}$ = 68 dB corresponding to the highest sound insulation determined in a series of measurements in subsidized residential buildings in Austria) under the assumption that the A-weighted sound level in the source room is 90 dB (with a frequency spectrum for music or spoken conversation). For lower sound levels in the source room the sound levels in the receiving room may be reduced correspondingly.



Note: Numbers indicated below graphs are $D_{nT,w}$, C, C_{tr}

Figure 1: Third octave band level in the neighbouring room transmitted from the source room with music or talking, 90 dB A-weighted, for different sound insulation and background level

The sound levels in the receiving room may be compared with the levels prevailing in the room at quiet times (learning, reading, sleeping). According to the time of day and land use (rural area, urban area) the background noise level may be between 25 and 35 dB with a frequency curve similar to the inverse A-weighting curve. This corresponds well with third-octave band analysis of background levels measured in practice. In figure 1d some examples are shown: limit curves for 25 and 35 dB A-weighted, a background level measured in a flat [11] and the background levels measured in the halls (without audience) in the Vienna Musikverein building [12].

The comparison of the values in Table 2 shows that the equivalent sound level of normal conversation (which corresponds also to radio and television turned down to moderate volume) is reduced to 19 dB in the neighbouring flat by the minimum required $D_{nT,w}$ = 55 dB and will then not be audible with respect to the background level of 25 dB; however, the maximum levels may be heard. The table also shows that music at home with an ensemble of 6 musicians (maybe a theoretical case) with an equivalent level of 91 dB requires sound insulation of $D_{nT,w}$ = 68 dB, to reduce the sound level to the background level of 25 dB in the neighbouring room, although single peaks will exceed this. Music at home with one violin with the equivalent level of 78 dB can be reduced below the background level of 25 dB in the neighbouring flat with the minimum required sound insulation $D_{nT,w}$ = 55 dB; however, single peaks will exceed the background noise and will become audible. Enhancing the sound insulation above 60 dB will give sufficient protection for the neighbour.

These examples show that sound levels of activities are different. The quietness desired may also be different. A study on sound levels in source and receiving room as basis for an assessment scheme for acoustical quality classes in buildings was worked out in the Netherlands [13].

Due to different activities and different needs, it is the task of a classification standard to indicate a range of classes of criteria deduced from sound levels of activities on the one hand and quietness to be achieved on the other hand. Customers, builders, architects and construction firms can use this and decide on the sound insulation they want to specify and to achieve.

4. CLASSIFICATION SCHEMES

In the last decade - obviously caused by the intentions of most building regulations to define only a just sufficient sound insulation and that the standard and expectations of living have grown - classification schemes have been developed in several countries and published in standards (or in other types of publications). The schemes include small or bigger descriptions of the acoustic conditions to be achieved with the different classes. However, these descriptions given for a certain level of sound insulation are very different. Some examples are given in Table 3. Only a rough comparison of schemes is possible, as different quantities to describe sound insulation are used in the different standards. The sound classification schemes in Europe have been compiled in some detail [14], showing the variety of quantities, numbers and classes used.

In Table 3 are found the main airborne sound insulation limits for the higher classes in countries NL [15], DK [16], SE [17], FI [18] and the corresponding verbal descriptions.

For a comparison of descriptors the following rough correlations can be used:

- For floors, the room height is usually constant or similar, i.e. volume/area = constant, $R'_w \approx D_{nT,w}$.
- For partitions and typical areas and room volumes, $R'_w \approx D_{nT,w}$ up to $R'_w \approx D_{nT,w} - 2$ dB; average $R'_w \approx D_{nT,w}$ -1 or $D_{nT,w} \approx R'_w$ + 1 dB.
- C usually is depending on type of construction 0 to -7 dB, for comparison estimation -1 dB.
- $C_{50\text{-}3150}$ 0 to -14 dB, depending on type of construction and value of R_w; for comparison estimation -5 dB.

The comparison shows some agreement between the limits in Table 3, but there is still a difference in the quantities applied, especially with respect to the low-frequency range.

Table 3: Criteria and descriptions of the two highest sound insulation classes in NL, DK, SE, FI – Airborne sound insulation

a) highest classes

NL	Class I $D_{nT,w} + C \geq 62$ dB	A quiet atmosphere with a high level of protection against intruding sound; very loud speech is generally not intelligible, normal speech and music not detectable, loud music and parties are detectable but hardly annoying. < 5 % annoyed
DK	Class A $R'_w + C_{50\text{-}3150} \geq 63$ dB	Excellent acoustic conditions, where the occupants are only occasionally disturbed by sound or noise; more than 90% judge the acoustic conditions to be good or very good
SE	Class A $R'_w + C_{50\text{-}3150} \geq 61$ dB	Very high acoustic quality
FI	Class A $R'_w + C_{50\text{-}3150} \geq 63$ dB	Higher than normal acoustic standard, most demanding class

b) second highest classes

NL	Class II $D_{nT,w} + C \geq 57$ dB	Under normal circumstances a good protection against intruding noise without too much restriction of the behaviour of the occupants, normal speech not detectable, loud speech and music sometimes detectable, but not intelligible, very loud speech and music, parties, clearly audible, but speech not intelligible. 5 – 10 % annoyed.
DK	Class B $R'_w + C_{50\text{-}3150} \geq 58$ dB	The occupants may be disturbed by noise only to a limited degree; 70-85 % judge the acoustic conditions as good or very good, less than 10 % as bad
SE	Class B $R'_w + C_{50\text{-}3150} \geq 57$ dB	High acoustic quality
FI	Class B $R'_w + C_{50\text{-}3150} \geq 58$ dB	Higher than normal acoustic standard

The numbers agree also somewhat with the following statements for the audibility of speech and music (provided a 20 dB background level) in (the highest) sound class III in the German VDI 4100 [19], where R'_w 59/60 dB for horizontal/vertical airborne sound insulation is required:

– Loud speech: generally not intelligible
– Speech with raised voice: not intelligible
– Normal speech: not audible
– Music played at home, loud radio and TV, parties: generally audible.

Explanations for all three VDI classes are found in Table 5. The statement of which type of activity may be heard to which extent by the neighbour is very useful to explain the acoustic comfort achieved by a certain insulation class.

A new detailed classification scheme is the DEGA-Empfehlung [20] (recommendation, not a standard) in Germany with 7 classes (2 classes with very low sound insulation below the DIN-requirements to cover existing old buildings, the “DIN-class” and 4 classes with requirements more stringent than DIN). For any class a verbal statement is given on the acoustic comfort. E.g. class A* with $R'_w \geq 72$ dB supplies an apartment with very good sound insulation ensuring living without annoyance and without considering the neighbours, like living in a detached house. Class A with $R'_w \geq 67$ dB supplies also an apartment with very good sound insulation ensuring living without annoyance and without considering much the neighbours, like living in a semidetached house with complete acoustic separation.

The numbers for R'_w in the upper classes of DEGA-Empfehlung seem high compared to the numbers shown for NL, DK, S, SF, but one has to consider that the latter include C or $C_{50-3150}$. Especially for constructions with high R_w, the values of $C_{50-3150}$ are quite low, so that high values for $R'_w + C_{50-3150}$ can not be achieved.

An example is shown in Fig. 2 for heavy floors [21]. It shows, that R'_w = 72 dB corresponds to about $R'_w + C_{50-3150}$ = 64 dB. The data for the correlation are worse for wooden floors where even with R'_w = 75 dB values of $R'_w + C_{50-3150}$ > 60 dB can not be achieved [21].

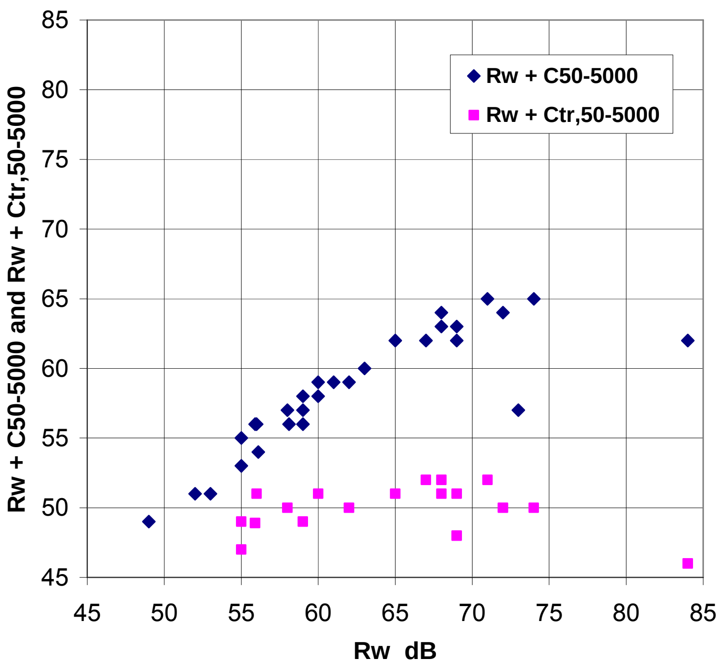


Figure 2: Weighted sound reduction index R_w and $R_w + C_{50-5000}$ and $R_w + C_{tr,50-5000}$ for heavy floors

The compilation of data on R_w and $C_{50-3150}$ of all types of building elements on the one hand and studies on the subjective response on sound insulation on the other hand show that the consideration of the low frequencies down to 50 Hz is very important. Sound insulation requirements - especially for higher acoustic comfort - should therefore include the frequency range down to 50 Hz.

Requirements for sound insulation in buildings should be based on $D_{nT,w}$ and not on R'_w, as the sound insulation perceived by persons in a room is described by $D_{nT,w}$ (and not R'_w). With R'_w, the sound insulation a person experiences, depends on the area of the partition or floor; that means in a large room (e.g. floor 25 m^2, volume 65 m^3) people hear 4 dB more from their neighbours above than from their neighbours to the left or right where the partition area is e.g. 10 m^2, if the neighbour TV is equally loud in both flats.

Joint efforts are being made in Europe to study the advantages and disadvantages of the variety of existing descriptors as applied in building acoustic requirements and to make proposals for harmonized sound insulation descriptors. Simultaneously, the many different classification schemes will be analyzed. It is planned to prepare a proposal for harmonized sound insulation descriptors and for a harmonized sound classification scheme. The studies include consideration of existing descriptors as well as new descriptors based on field surveys and psychoacoustic evaluation of sound insulation in a laboratory setup. As a tool on the way, it is also planned to develop a uniform questionnaire to apply for social surveys, implying that results from different countries can be compared.

A European network - COST Action TU0901 [22] - has been established, and it is hoped that the work on the European level on harmonizing sound insulation aspects in urban housing will succeed to agree on uniform quantities to describe airborne and impact sound insulation performance and to develop a reasonable classification scheme for national implementation.

5. HOW TO EXPLAIN PROTECTION PROVIDED BY DIFFERENT SOUND CLASSES

Sound classification schemes exist in nine countries in Europe [14]. They are very different, including different ways to explain the protection supplied by different classes. An indication of the qualitative and quantitative diversity of descriptions is found in Table 3. What is "Higher than normal acoustic standard"? Which protection against neighbour noise does it mean in practice? More explanation is found in the Danish standard DS 490 [15], partly under definitions and partly in an annex. The summarized information is found in Table 4.

Table 4: Occupants' expected satisfaction for different sound classes according to DS 490:2007. Summary based on information in DS 490.

Sound classes describing acoustic conditions in dwellings		Occupants' evaluation	
Class	**Characteristics according to DS 490**	**Good or very good**	**Poor**
A	**Excellent acoustic conditions** Occupants will be disturbed only occasionally by sound or noise	> 90%	
B	**Considerable improvement compared to minimum given in class C** Occupants may be disturbed sometimes by sound or noise	70 to 85%	< 10%
C	**Sound class intended as minimum requirement for new buildings** Less than 20% of occupants are expected to be disturbed by sound or noise	50 to 65%	< 20%
D	**Sound class for older buildings with less satisfactory acoustic conditions** Intended for e.g. renovated dwellings. Not intended for new buildings.	30 to 45%	25 to 40%
Note: Within each sound class the percentage satisfied or dissatisfied occupants may differ somewhat from one acoustic criterion to another. The grouping is mainly based on the subjective assessments of airborne sound between dwellings and impact sound from adjacent dwellings. For details, see DS 490.			

Although more quantitative than "Higher than normal acoustic standard", the explanations in Table 4 may not be very useful for a prospective occupant of a dwelling in multi-storey housing, because it is not related to personal activities and needs, but more to statistics.

A more informative description is found in the German Guideline VDI 4100 [19], see Table 5, where different types of neighbour activities are listed and the perception in a neighbouring dwelling indicated for each activity and sound class. The descriptions could be further elaborated for more types of activities and other classes than defined in VDI 4100. In addition, the validity for other descriptors and newer building practice should be evaluated, and the findings applied in a European classification scheme.

Table 5: VDI 4100:2007– Perception of customary noises from neighbouring dwellings and assignment to three sound insulation classes (SSt) – Ref.: VDI 4100 [19], Table 1.

Type of noise emission	Perception of immission from neighbouring dwelling Assumptions: • Typical evening A-weighted background noise about 20 dB • Customary large living spaces assumed		
	SSt I	SSt II	SSt III
Loud speech	intelligible	in general intelligible	in general not intelligible
Raised speech	in general intelligible	in general not intelligible	not intelligible
Normal speech	in general not intelligible	not intelligible	not audible
Walking noise	in general disturbing	in general no more disturbing	not disturbing
Noise from building service installations	unreasonable annoyances are in general avoided	occasionally disturbing	not or only seldom disturbing
Music, loudly adjusted radio and television sets, parties	clearly audible		in general audible

Verbal explanations of classes also show clearly that minimum sound insulation as defined in regulations protects only people with a normal sensitivity against noise against disturbance caused by "normal" neighbourly activities. It also becomes evident that occupants themselves might need to cut down their activities out of consideration for their neighbours.

6. CONCLUSIONS

Social surveys in different European countries show that a considerable percentage of people living in multifamily houses is annoyed by the noise from the neighbours, even if building regulations requiring minimum sound insulation have existed for several decades. This "annoyance" is quite understandable, as the existing regulations only define protection for normally sensitive persons against strong disturbance under the assumption of a "usual" behaviour, i.e. not loud music or running children. A harmonized sound classification scheme therefore should be established based on the sound levels of different living activities and different levels of desired quietness. The protection against intruding sound given by the various classes should be explained by generally understandable verbal statements, thus enabling people to know what they choose.

A joint European Action TU0901 [22] has been approved, aiming at preparing proposals for harmonized sound insulation descriptors and for a European classification scheme. On the way, other tasks will be dealt with, one of them being preparation of uniform questionnaires for social surveys and research on annoyance of neighbour noise.

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