Protective Noise Levels

Condensed Version of EPA Levels Document

PURPOSE

This publication is intended to complement the EPA's "Levels Document,"* the 1974 report examining levels of environmental noise necessary to protect public health and welfare. It interprets the contents of the Levels Document in less technical terms for people who wish to better understand the concepts presented there, and how the protective levels were identified. In that sense, this publication may serve as an introduction, or a supplement, to the Levels Document.
*"Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," EPA/ONAC 550/9-74-004, March, 1974.

INTRODUCTION

During the last 20 years there has been increasing concern with the quality of the environment. Along with air and water contaminants, noise has been recognized as a serious pollutant. As noise levels have risen, the effects of noise have become pervasive and more apparent.

Noise is defined as "unwanted sound." In the context of protecting the public health and welfare, noise implies adverse effects on people and the environment. Noise causes hearing loss, interferes with human activities at home and work, and is in various ways injurious to people's health and well-being. Although hearing loss is the most clearly measurable health hazard, noise is also linked to other physiological and psychological problems.

Noise annoys, awakens, angers and frustrates people. It disrupts communication and individual thoughts, and affects performance capability. Noise is one of the biological stressors associated with everyday life. Thus, the numerous effects of noise combine to detract from the quality of people's lives and the environment.

Noise emanates from many different sources. Transportation noise, industrial noise, construction noise, household noise, and people and animal noise are all large-scale offenders. It is important, then, to examine the total range and combination of noise sources and not to focus unduly on any one source.

Through the Noise Control Act of 1972, Congress directed the Environmental Protection Agency (EPA)to publish scientific information about the kind and extent of all identifiable effects of different qualities and quantities of noise. EPA was also directed to define acceptable levels under various conditions which would protect public health and welfare with an adequate margin of safety. The EPA collaborated with other Federal agencies and the scientific community to publish a "Levels Document,"* which would fulfill these requirements in the Noise Control Act.

Initial public reaction was quite favorable, but it was discovered that the document was too complex, too technical, and too long for some audiences. This summary presents the contents of the Levels Document in less technical terms. It defines the basic measurement of noise, analyzes noise exposure, and presents the best understood effects of noise - hearing damage, speech interference, and annoyance -using information contained in the Levels Document. The identified protective levels are then summarized, followed by a number of often-asked questions and answers about the Levels Document.

No attempt has been made here to incorporate recent research findings pertaining to effects of noise on people. Considerable new information has developed since initial publication of the Levels Document, including new findings on community response to noise, sleep disruption, and speech interference. Summaries and analyses of some recent information on noise effects are available through EPA and other agencies.

*"Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety", EPA 550/9-74-004, March, 1974, U.S. Environmental Protection Agency, Washington, D.C. 20460.

ABOUT SOUND

The sound we hear is the result of a sound source inducing vibration in the air. The vibration produces alternating band of relatively dense and sparse particles of air, spreading outward from the source in the same way as ripples do on water after a stone is thrown into it. The result of the movement of the particles is a fluctuation in the normal atmospheric pressure, or sound waves. These waves radiate in all directions from the source and may be reflected and scattered or, like other wave actions, may turn corners.

When the source stops vibrating, the sound waves disappear almost instantaneously, and the sound ceases. The ear is extremely sensitive to sound pressure fluctuations, which are convened into auditory sensations.

Sound may be described in terms of three variables:

1. Amplitude (perceived as loudness)
2. Frequency (perceived as pitch)
3. Time pattern

Amplitude

Sound pressure is the amplitude or measure of the difference between atmospheric pressure (with no sound present) and the total pressure (with sound present). Although there are other measures of sound amplitude, sound pressure is the fundamental measure and is the basic ingredient of the various measurement descriptors in the next section, "Measurement of Environmental Noise."

The unit of sound pressure is the decibel (dB); thus it is said that a sound pressure level is a certain number of decibels. The decibel scale is a logarithmic scale, not a linear one such as the scale of length. A logarithmic scale is used because the range of sound intensities is so great that it is convenient to compress the scale to encompass all the sounds that need to be measured. The human ear has an extremely wide range of response to sound amplitude. Sharply painful sound is 10 million times greater in sound pressure than the least audible sound. In decibels, this 10 million to 1 ratio is simplified logarithmically to 140 dB.

Another unusual property of the decibel scale is that the sound pressure levels of two separate sounds are not directly (that is, arithmetically) additive. For example, if a sound of 70 dB is added to another sound of 70 dB, the total is only a 3-decibel increase (to 73 dB), not a doubling to 140 dB. Furthermore, if two sounds are of different levels, the lower level adds less to the higher as this difference increases. If the difference is as much as 10 dB, the lower level adds almost nothing to the higher level. In other words, adding a 60 decibel sound to a 70 decibel sound only increases the total sound pressure level less than one-half decibel.

Frequency

The rate at which a sound source vibrates, or makes the air vibrate, determines frequency. The unit of time is usually one second and the term "Hertz" (after an early investigator of the physics of sound) is used to designate the number of cycles per second. The human ear and that of most animals has a wide range of response. Humans can identify sounds with frequencies from about 16 Hz (Hertz) to 20,000 Hz. Because pure tones are relatively rare in real-life situations, most sounds consist instead of a complex mixture of many frequencies.

Time Pattern

The temporal nature of sound may be described in terms of its pattern of time and level: continuity, fluctuation, impulsiveness, intermittency. Continuous sounds are those produced for relatively long periods at a constant level, such as the noise of a waterfall. Intermittent sounds are those which are produced for short periods, such as the ringing of a telephone or aircraft take-offs and landings. Impulse noises are sounds which are produced in an extremely short span of time, such as a pistol shot or a hand clap.

Fluctuating sounds vary in level over time, such as the loudness of traffic sounds at a busy intersection.

Measurement of Environmental Noise: Sound Descriptors

EPA has adopted a system of four "sound descriptors" to summarize how people hear sound and to determine the impact of environmental noise on public health and welfare. These four descriptors are: the A-weighted Sound Level, A-weighted Sound Exposure Level, Equivalent Sound Level, and Day-Night

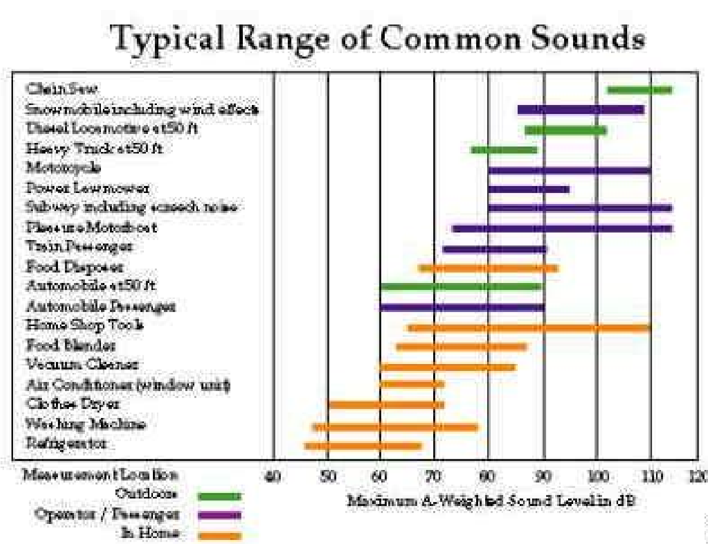
Sound Level. They are related but each is most useful for a particular type of measurement. The descriptors and some examples of their uses are described below.

A-Weighted Sound Level

One's ability to hear a sound depends greatly on the frequency composition of the sound. People hear sounds most readily when the predominant sound energy occurs at frequencies between 1000 and 6000 Hertz (cycles per second). Sounds at frequencies above 10,000 Hertz (such as high-pitched hissing) are much more difficult to hear, as are sounds at frequencies below about 100 Hz (such as a low rumble). To measure sound on a scale that approximates the way it is heard by people, more weight must be given to the frequencies that people hear more easily.

A method for weighting the frequency spectrum to mimic the human ear has been sought for years. Many different scales of sound measurement, including A-weighted sound level (and also B, C, D, and E-weighted sound levels) have evolved in this search. A-weighting was recommended by EPA to describe environmental noise because it is convenient to use, accurate for most purposes, and is used extensively throughout the world. Figure 1 shows the A-weighted levels of some environmental noises. Note that these ranges of measured values are the maximum sound levels.

Fig. 1 - Typical Range of Common Sounds¶



The A-weighting of frequency also is used in the three descriptors discussed below. When used by itself, an A-weighted decibel value denotes either a sound level at a given, instant, a maximum level, or a steady-state level. The following three descriptors are used to summarize those levels which vary over time.

Sound Exposure Level

Since the levels of many sounds change from moment to moment, this variation must also be accounted for when measuring environmental noise. One method for measuring the changing magnitude of sound levels is to trace a line on a sheet of moving paper, so that the movement of the pen is proportional to the sound level in decibels. Figure 2 illustrates such a recording, about which several features are noteworthy. First, the sound level varies with time over a range of about 30 dB. Second, the sound appears to be characterized by a fairly steady-state lower level, upon which are superimposed sound levels associated with individual events. This fairly constant lower level is often called the background ambient sound level.

Figure 2 - Typical Outdoor Sound Measured on a Quiet Suburban Street

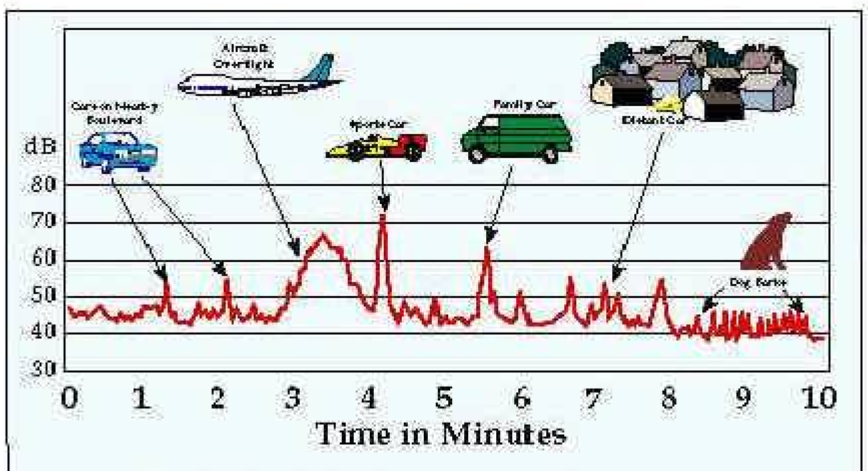
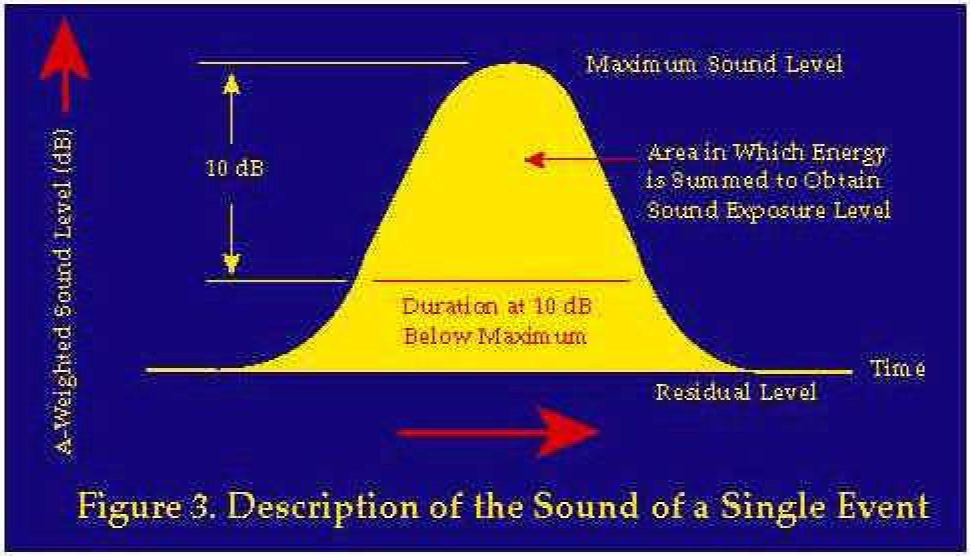


Figure 2. Typical Outdoor Sound Measured on a Quiet Suburban Street

Each single event in Figure 2 may be partially characterized by its maximum level. It may also be partially characterized by its time pattern. In the example, the sound level of the aircraft is above that of the background ambient level for about a minute, whereas the sound levels from cars are above the background level for much less time.
The duration of sounds with levels that vary from moment to moment is more difficult to characterize. One way is to combine the maximum sound level with the length of time during which the sound level is greater than a certain number of decibels below the maximum level -- for example, the number of seconds that the sound rises from 10 dB below maximum, as in Figure 3.

Figure 3. Description Of The Sound Of A Single Event



Using this procedure one can measure the total energy of the sound by summing the intensity during the exposure duration. This procedure produces the second measurement descriptor, sound exposure level (Ls), referred to in the Levels Document as the single event noise exposure level (SENEL).

Equivalent Sound Level

Yet another method of quantifying the noise environment is to determine the value of a steady-state sound which has the same A-weighted sound energy as that contained in the time-varying sound. This is the third measurement descriptor, termed the Equivalent Sound Level (Leq). The Equivalent Sound Level is a single value of sound level for any desired duration, which includes all of the time-varying sound energy in the measurement period. In Figure 2, for example, the Leq equals about 58 dB, indicating that the amount of sound energy in all the peaks and valleys in the figure is equivalent to the energy in a continuous sound of 58 dB.

The major virtue of the Equivalent Sound Level is that it correlates reasonably well with the effects of noise on people, even for wide variations in environmental sound levels and time patterns. It is used when only the durations and levels of sound, and not their times of occurrence (day or night), are relevant. It is easily measurable by available equipment. It also is the basis of a fourth and final measurement descriptor of the total outdoor noise environment, the Day-Night Sound Level (Ldn).

Day-Night Sound Level

The Day-Night Sound Level is the A-weighted equivalent sound level for a 24-hour period with an additional 10 dB weighting imposed on the equivalent sound levels occurring during nighttime hours (10 pm to 7 am). Hence, an environment that has a measured daytime equivalent sound level of 60 dB and a measured nighttime equivalent sound level of 50 dB, can be said to have a weighted nighttime sound level of 60 dB (50 + 10) and an Ldn of 60 dB. Examples of measured Ldn values are shown in Figure 4.

Figure 4 - Examples of Outdoor Day-Night Average Sound Levels in dB Measured at Various Locations

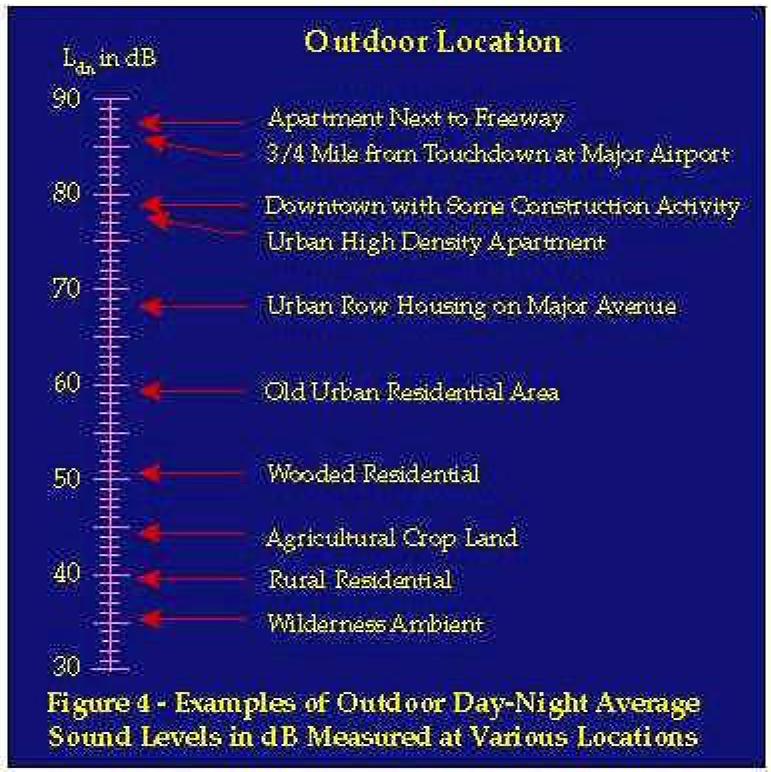


Table 1 summarizes the use of the four sound descriptors used by EPA.

Table I. Descriptors of Sound*

TYPICAL USE	NAME OF DESCRIPTOR	NATURE OF DESCRIPTOR
To describe steady air-conditioning sound in a room or measure maximum sound level during a vehicle passby with a simple sound level meter.	A-weighted Sound Level	The momentary magnitude of sound weighted to approximate the ear's frequency sensitivity.
To describe noise from a moving source such as an airplane, train, or truck.	A-weighted Sound Exposure Level	A summation of the energy of the momentary magnitudes of sound associated with a single event to measure the total sound energy of the event.
To measure average environmental noise levels to which people are exposed.	Equivalent Sound Level	The A-weighted sound level that is "equivalent" to an actual time varying sound level, in the sense that it has the same total energy for the duration of the sound.
To characterize average sound levels in residential areas throughout the day and night.	Day-Night Sound Level	The A-weighted equivalent sound level for a 24-hour period with 10 decibels added to nighttime sounds (10 pm - 7 am).

*The unit for all descriptors is the decibel.

Levels Of Environmental Noise In The United States

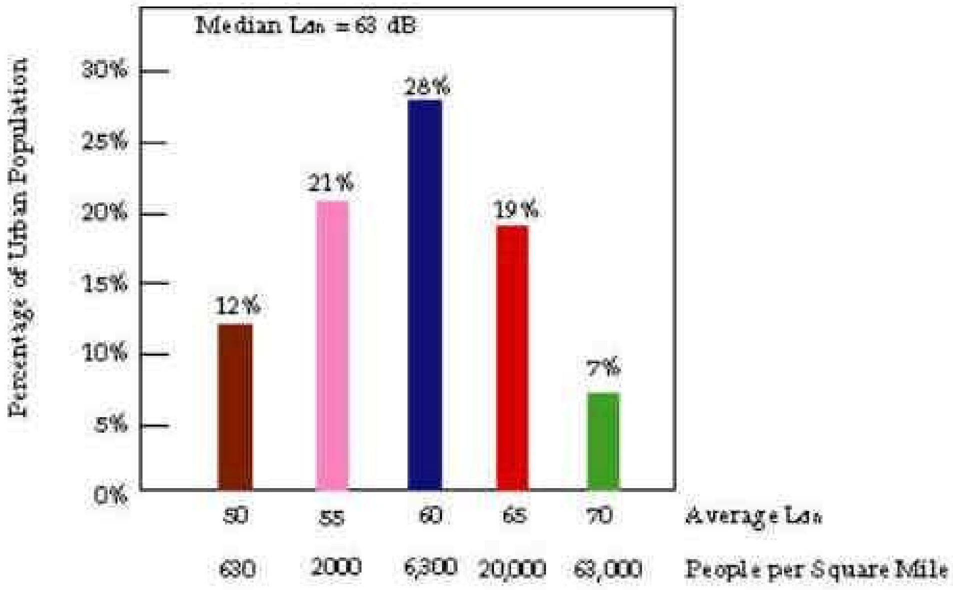
In residential areas of the United States, major contributions to outdoor noise come from transportation, industrial, construction, human and animal sources. Inside homes, appliances, radio and television, as well as people and animals, are predominant noise sources. On the job, workplace equipment can create moderate to extremely high levels of noise. The daily noise exposure of people depends on how much time they spend in different outdoor and indoor locations and on the noise environments in these places. Typical daily exposure patterns are discussed in this section, following short descriptions of outdoor and indoor levels of environmental noise throughout the United States.

Outdoor Levels

The noise environment outside residences in the United States can be highly variable. As seen in Figure 4, outdoor Day-Night Sound Levels in different areas vary over a range of 50 dB. Levels occur as low as Ldn = 30 to 40 dB in wilderness areas and as high as Ldn = 85 to 90 dB in urban areas.

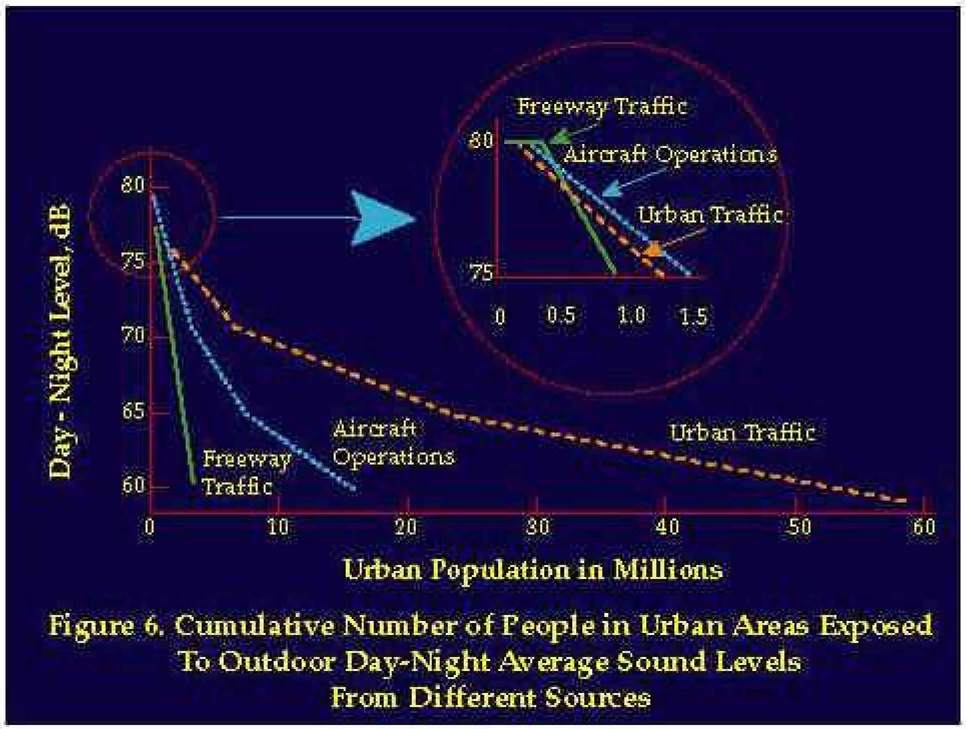
Most Americans live in areas with a much smaller ranger of outdoor noise levels. Figure 5 shows that for urban dwellers (roughly 135 million people, more than half the U.S. population), 87% live in areas of Ldn = 48 and higher from traffic noise alone. Most of the other 13% of the urban population experience lower noise levels than those of Figure 5. Figure 5 also shows that nearly half of the urban population live in areas exposed to traffic sounds that range over only 5 dB (Ldn = 55 to 60 dB). Rural populations enjoy average outdoor sound levels generally lower than Ldn = 50 dB.

Figure 5 - Estimated Percentage Of Urban Population Exposed To Outdoor Day-Night Sound Levels Due To Traffic



It is useful to know the number of people living in areas characterized by different levels of environmental noise. Figure 6 presents estimates for urban traffic, freeway traffic, and aircraft noise. The figure shows that urban traffic noise is much more widespread than either aircraft or freeway noise, but the figures are not strictly additive, because many of the people counted in one category are also exposed to another category of noise. Fifty-nine million people live in areas with urban traffic noise of Ldn = 60 dB or higher, in contrast to only 16 million and 3.I million people who live in areas with outdoor levels of Ldn = 60 dB or higher for aircraft and freeway noise, respectively. On the other hand, more people are exposed to higher levels of noise from freeway and aircraft operations than from urban traffic: about 300,000 people live in areas exposed to levels of Ldn = 80 dB or higher from freeway traffic; 200,000 from aircraft operations; and 100,000 from urban traffic. Bear in mind, however, that there may be differences between individual at-ear exposure levels and outdoor levels, because people move from place to place for varying amounts of time.

Figure 6. Cumulative Number of People in Urban Areas Exposed to Outdoor Day-Nigh Average Sound Levels From Different Sources



Relationship Between Indoor and Outdoor Levels

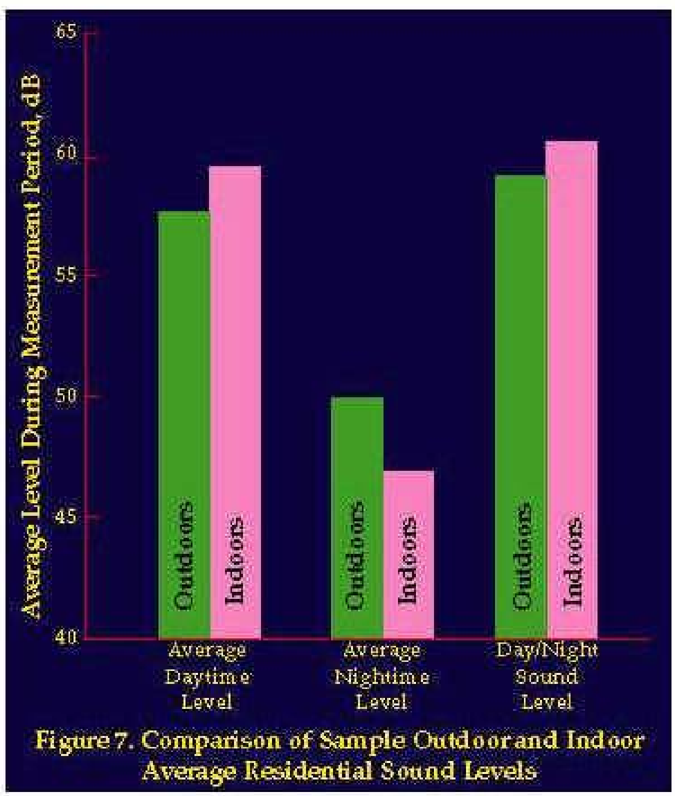
The contribution of outdoor noise to indoor noise levels is usually small. That pan of a sound level within a building caused by an outdoor source obviously depends on the source's intensity and the sound level reduction afforded by the building. Although the sound level reduction provided by different buildings differs greatly, dwellings can be categorized into two broad classes-- those built in warm climates and those built in cold climates. Further, the sound level reduction of a building is largely determined by whether its windows are open or closed. Table II shows typical sound level reductions for these categories of buildings and window conditions, as well as an approximate national average sound level reduction.

Table II
Typical Sound Level Reductions of Buildings

	Windows Opened	Windows Closed
Warm Climate	12dB	24dB
Cold Climate	17dB	27dB
Approximate National Average	15dB	25dB

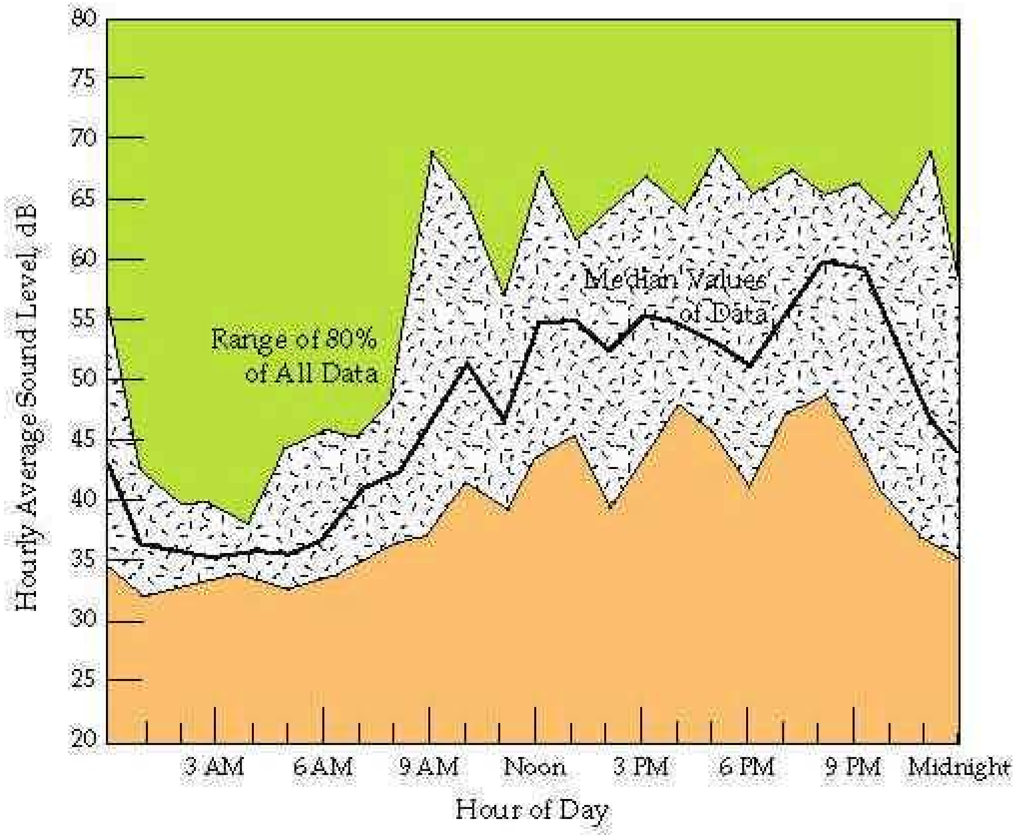
Sample measurements of outdoor and indoor noise levels during 24-hour periods are depicted in Figure 7. Despite the sound level reduction of buildings, indoor levels are often comparable to or higher than levels measured outside. Thus, indoor levels often are influenced primarily by internal noise sources such as appliances, radio and television, heating and ventilating equipment, and people. However, many outdoor noises may still annoy people in their homes more than indoor noises do. Indeed, people sometimes turn on indoor sources to mask the noise coming from outdoors.

Figure 7 - Comparison of Sample Outdoor and Indoor Average Residential Sound Levels



An example of the range of hourly sound levels measured inside living areas in plotted for each hour of the day in Figure 8. The figure shows the median levels and the range of levels observed for 80% of the data. During late night hours the typical hourly sound level was approximately 36 dB. This level was probably dominated by outdoor noise. However, during the day, the hourly average levels ranged from about 40 to 70 dB, indicating the wide range of activities in which people engage.

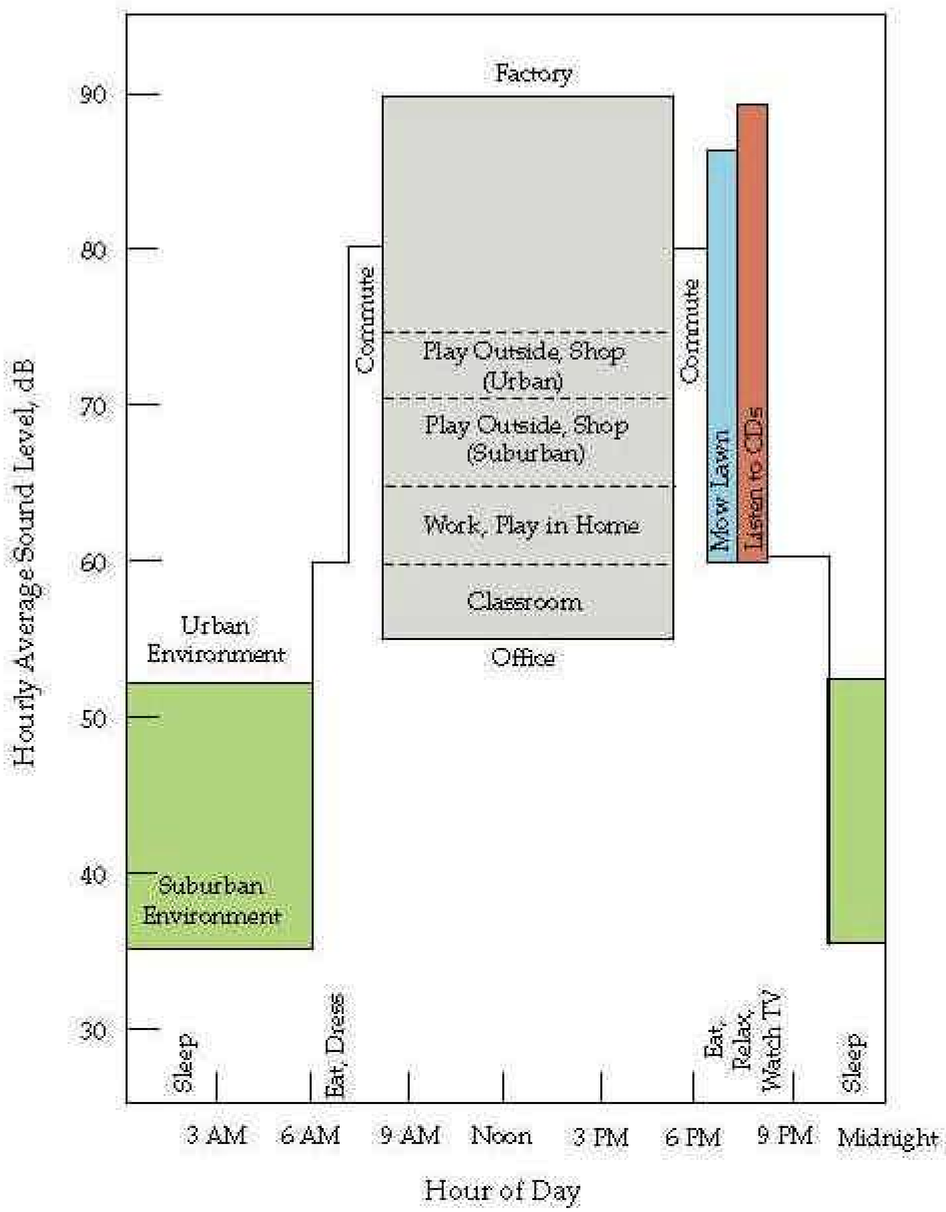
Fig. 8 - Time Pattern of Hourly Indoor Residential Sound Levels



Individual Noise Exposure Patterns

During a 24-hour period, people are exposed to a wide range of noises, including noise at home, work, school, places of recreation, shopping establishments, and while enroute to these or other. locations. Clearly, no single exposure pattern can be typical of all people, or even of those people who follow a common life style. Figure 9 shows hypothetical exposure patterns for broad classes of people. From these levels and some assumptions about the hours spent at different daytime activities, 24-hour average sound levels can be estimated for factory and office workers, housewives, and preschool and school-age children. Estimates based on these assumptions are found in Table III.

Fig. 9 - Generalized Individual Noise Exposure Patterns



For most people, nighttime noises do not contribute significantly to the 24-hour average. For many, the 24-hour average is determined primarily by the noise exposure of a single activity, frequently occurring for a short period of time.

Table III
Hypothetical Examples of Noise Exposures of Individuals
24-Hour Average Sound Level, dB

Individual	Urban Environment	Suburban Environment
Factory Worker	87	87
Office Worker	72	70
Housewife	64	67
School Child	77	77

Hearing Damage from Environmental Noise

There is no question that exposure to certain levels of noise can damage hearing. However, determining exposure levels that protect hearing with an adequate margin of safety is a complicated matter.

This is because hearing is a complex ability that cannot be summarized by a single number in the way an individual's height or weight can be described. In fact, sizable differences exist between individuals' hearing abilities. Hearing acuity tends to change progressively with age. Also, environmental noise exposure may vary considerably from moment to moment, so that specification of protective levels should include dynamic considerations. Further, relationships between hearing damage and noise exposure must be inferred, since available scientific information was gathered from groups of people who differed not only in noise exposure, but also in other important ways. Finally, individual and group noise exposures (especially over a working lifetime) are rarely known with precision.

In reaching conclusions about hearing loss, then, one must rely to a degree on assumptions, hypotheses, and extrapolations from existing data. Since complete agreement within the scientific community on these matters is lacking, an attempt was made in the Levels Document to consider alternative assumptions and hypotheses to ensure that the methods used to derive protective levels were based on the most defensible practice. As new data become available these levels may change slightly.

Basic Premises Involved in Determining Protective Levels

1. Changes in ability to hear in the region of 4000 Hz are the most important signs of irreversible hearing loss, indicating actual physiological destruction within the hearing mechanism. This frequency is usually the first frequency affected when the ear is damaged by exposure to noise. Furthermore, the protection of hearing acuity at this frequency is critical for understanding of speech and appreciation of music and other sounds.

2. Changes in individual hearing level, like changes in height or weight, are only significant if they are sizable. Changes smaller than 5 dB are considered insignificant.

3. At all ages, it is assumed that hearing acuity cannot be damaged by sounds that cannot be heard. This may be important in that aging and other causes may produce appreciable shifts in hearing.

4. Because hearing ability varies from person to person, recommendations must be made in terms of a critical percentage of the population, ranked with superior hearing over the remainder. EPA's recommendations were based on the 96th percentile-that is, on providing protection for 96% of the people. It is assumed that people with poorer hearing than the 96th percentile are not affected by noise of typical levels (see 3 above), so that the recommendations protect virtually the entire population.

5. An individual's total noise exposure is evaluated by an "equal energy" rule: two noise exposures are expected to produce equal hearing loss if the product of exposure intensity and exposure time are equal. This rule allows a 3-dB decrease in sound pressure level (expressed in dB) for each doubling of the duration. Thus an exposure of 76 dB for one hour is equivalent to 73 dB for two hours, or 70 dB for four hours. This procedure is probably accurate for exposures of 30 minutes or more. It is also more protective for very short exposures and for noise that fluctuates greatly in level.

6. Intermittent noise produces less hearing damage than the "equal energy" rule would predict. To be considered intermittent for this purpose, a noise must fall below 65 dB for 10% of each hour and have peaks that exceed the background level by 5 to 15 dB. Intermittent noise is assumed to produce 5 dB less effect than does continuous noise of the same average level.

Calculation of the Maximum Allowable Noise Exposure

Three major scientific studies have attempted to assess hearing damage for various noise exposures. All are based on a comparison of groups of noise-exposed people and comparable non-exposed groups. All three studies attempted to predict hearing loss as a function of noise exposure of a certain percentage of people. Because these studies were of exposure to high-level noise, extrapolations of the data were necessary to estimate the protective exposure level that would produce minimal hearing loss: less than 5 dB at 4000 Hz for 96% of the people.

Forty years of exposure (250 working days per year) to a noise level of 73 dB for 8 hours per day was calculated to produce a hearing loss smaller than 5 dB for 96% of the people. This is the basic datum used to calculate hearing-protective levels of noise exposure. To use it in specific situations, certain corrections must be applied. One correction is to determine the yearly (rather than working day) level (250 to 365 days). This consideration amounts to a reduction 1.6 dB. Another correction, based on exposure on a 24-hour rather than 8-hour basis, produces an additional reduction of 5 dB.

Table IV contains at-ear noise exposure levels that produce negligible hearing losses for both 8-hour and 24-hour exposure on a yearly and working day basis. The 8-hour calculation assumes the remaining 16 hours of the day are spent in relative quiet. Since an individual often experiences intense noise exposure outside of working hours (for example, while using noisy appliances or pursuing noisy recreation), protection on a 24-hour basis 365 days per year requires exposure of an intermittent variety at an equivalent level of less than 71.4 dB. This value is rounded to 70 dB to provide a slight margin of safety. Exposure to greater levels would produce more than 5 dB hearing loss in at least some of the population.

Table IV
(At-Ear) Exposure Levels that Produce No More Than 5 dB Noise-Induced Hearing Damage Over a 40-Year Period

		Steady (continuous) Noise	Intermittent Noise	With Margin of Safety
Leq, 8 hour	250 day/year	73	78	
	365 day/year	71.4	76.4	75
Leq, 24 hour	250 day/year	68	73	
	365 day/year	66.4	71.4	70

Discussion of Assumptions

Several assumptions have been made in calculating the 24-hour yearly hearing-protective level of 70 dB. It is reasonable to ask how alternative assumptions would affect this level, and what the range of error might be.

Q. How would the recommended level be affected by a change in the percentage of the population protected?

A. Reducing the 96th percentile value to the 50th percentile (i.e., protecting half the population) would increase the protective level value from 70 dB to 77 dB.

Q. Since agreement on the value of the intermittency correction is imperfect, what other values might be used?

A. The estimated intermittency correction used in the Levels Document is 5 dB. The true intermittency correction is probably within the range 0 to 15 dB.

Q. How accurate is the equal energy assumption?

A. The equal energy assumption when applied to the long times (8 hours to 24, or 250 to 365 days) is fairly accurate. It may be subject to error

Q. How meaningful are the basic studies of hearing damage risk?

A. The probable errors of estimates in the three basic studies cannot be stated with absolute accuracy. There are a number of problems in extrapolating percentages of the population damaged from relatively high exposure levels to the protective level. Also, there is the problem of determining the amount of hearing damage when the control (non-exposed) population is subject to high levels of non-occupational noise. Thus, the 70 dB protective level is simply the best present estimate, subject to change if better data become available.

Speech Communication

Communication. is an essential element of human society, and speech is its most convenient form of expression. Interference with speech can degrade living directly, by disturbing normal social and work-related activities, and indirectly, by causing annoyance and stress. Sometimes the communications disturbed by noise are of vital importance, such as warning signals or cries for assistance. Prolonged speech interference and resulting annoyance are clearly not consistent with public health and welfare.

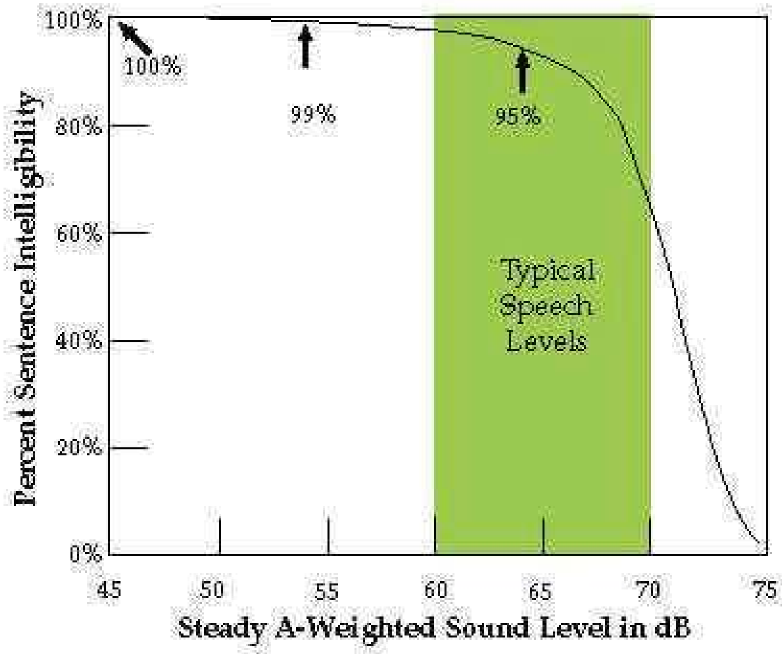
Speech interference from environmental noise can occur at home, at work, during recreation, inside vehicles, and in many other settings. Of chief concern for current purposes are the effects of noise on face-to-face conversations (indoors and outdoors), telephone conversations, and radio or television use.

The degree to which noise disturbs speech depends not only on physical factors (such as noise levels, vocal effort, distances between talkers and listeners, and room acoustics), but also on non-physical factors. The latter include the speaker's enunciation, the familiarity of the listener with the speaker's vocabulary and accent, the topic of conversation, the listener's motivation, and the hearing acuity of the listener. Years of research on speech intelligibility have produced considerable information about how these factors interact. Accurate predictions of speech intelligibility can be based on average noise levels and distances between speakers and listeners.

Speech Interference Indoors

The solid line in Figure 10 shows the effects of steady masking noise on sentence intelligibility for persons with normal hearing in a typical living room. At distances greater than about one meter from the speaker, the level of speech is fairly constant throughout the room.

Fig. 10 - Indoor Sentence Intelligibility



The highest noise level that permits relaxed conversation with 100% sentence intelligibility throughout the room is 45 dB. People tend to raise their voices when the background noise exceeds 45-50 dB.

Speech Interference Outdoors

The sound level of speech outdoors decreases with increasing distance between speaker and listener. Table V shows distances between speaker and listener for satisfactory outdoor speech intelligibility at two levels of vocal effort in steady background noise levels.

The levels for normal and raised-voice "satisfactory conversation" shown in Table V permit sentence intelligibility of 95% at each distance. Ninety-five percent sentence intelligibility usually permits reliable communication because of the redundancy in normal conversation.

If the noise levels in Table V are exceeded, the speaker and listener must either move closer together or expect reduced intelligibility. For example, consider a conversation at normal vocal effort at a distance of three meters in a steady background noise of 56 dB. If the background level increases to 66 dB, the speakers either will have to move closer (to one meter apart) to maintain the same intelligibility, or alternatively, raise their voices appreciably. If they remain three meters apart without raising their voices, speech intelligibility would drop considerably.

Table V
Steady A-weighted Sound Levels That Allow Communication with 95 Percent Sentence Intelligibility Over Various Distances Outdoors for Different Voice Levels

COMMUNICATION DISTANCE (meters)	0.5	1	2	3	4	5
Normal Voice (dB)	72	66	60	56	54	52
Raised Voice (dB)	78	72	66	62	60	58

Discussion

In summary, an Ldn of 45 dB permits virtually 100% intelligibility inside buildings. Assuming that a typical home reduces outdoor noise by 15 dB, the outdoor noise level should be no greater than Ldn = 60 dB to permit 100% intelligible speech indoors. Allowing a 5 dB. margin of safety, the outdoor level should be Ldn = 55 dB. This outdoor level would also guarantee sentence intelligibility of 95% outdoors with normal voice levels at a distance of three meters.
Q. What do percentages of sentence intelligibility signify?
A. A given percentage of sentence intelligibility, such as 95% or 99%, indicates the proportion of key words (in a group of sentences) which are correctly heard by normal-hearing listeners.
Q. How are the speech criteria affected by the fact that people tend to raise their voices in noise?
A. The speech criteria are based on the principle that an adequate communication environment does not necessitate raised voices.
Q. How do the identified continuous equivalent levels relate to the fact that, in everyday life, noise fluctuates and is intermittent in nature?
A. The Levels Document tabulated speech interferences for different combinations of levels and durations to test the limits of certain Leq values under intermittent conditions. It is acknowledged that, given equal Leq values, fluctuating noise may reduce less total speech interference than continuous noise on average. On the other hand, during those times when the higher level noises occur, the speech interference will be greater than its average value.

Activity Interference and Annoyance

Noise interferes with human activities to varying degrees. Intruding noises can interfere with human activities by distracting attention and by making activities more difficult to perform, especially when concentration is needed. Interference from noise can even make some activities (such as communication or sleep) virtually impossible. Except in the case of speech interference, however, the degree of interference is hard to specify and difficult to relate to the level of noise exposure.

Because people's reactions to time-varying noise differ from moment to moment, and because people's reactions differ in general, protective levels for annoyance and activity interference are determined from data collected from groups of people, rather than from individuals. Fortunately, considerable data from social surveys of community reactions to noise exposure are available for this purpose. Although there are some shortcomings in practically all such data, sufficient agreement exists to allow confident predictions of the noise levels that lead to certain degrees of activity interference and annoyance.

Activity Interference

Social surveys most often have been used to assess community reaction to noise exposure around airports. Table VI shows the percentage of people who reported noise interference with activities among a larger group which was extremely disturbed by aircraft noise.
It is hardly surprising that four of the nine activities in Table VI involve listening. Aircraft noise may also be found annoying because it may startle people, cause houses to shake, or elicit fear of a crash.

Another widely studied source of community noise exposure is vehicular traffic. Activity interference produced by traffic noise closely resembles that of aircraft noise, since interference with conversation, radio, television, and telephone use are all high on the list of activities disturbed.

Table VI
Percentage of Those People Who Were Highly Disturbed by Aircraft Noise, by Activity Disturbed

ACTIVITY	PERCENT
TV-Radio Reception	20.6
Conversation	14.5
Telephone	13.8
Relaxing Outside	12.5
Relaxing Inside	10.7
Listening to Records/Tapes	9.1
Sleep	7.7
Reading	6.3
Eating	3.5

Community Reactions to Noise

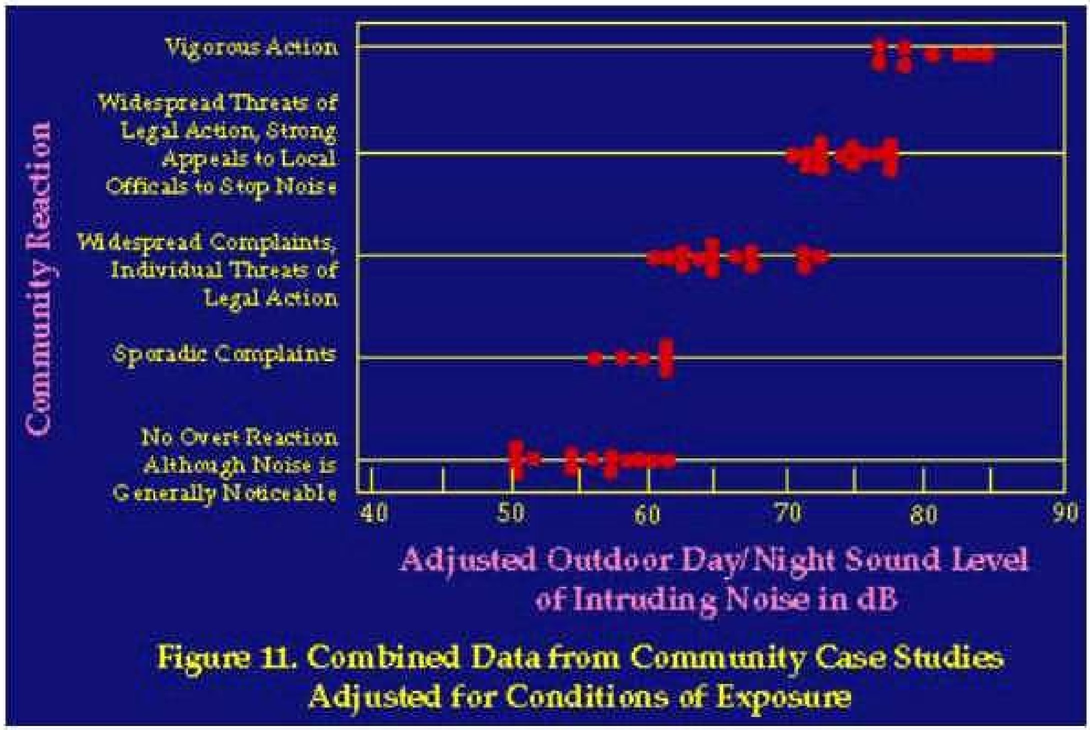
Two major indices of the cumulative effects of environmental noise on people are (A) specific actions taken by individuals or groups (such as complaints), and (B) responses to social survey questionnaires. Over the fast 25 years, numerous studies have been conducted to increase understanding of the relationship between noise exposure and its effects on people in communities.

Several factors beyond the magnitude of exposure have been found to influence community reaction. These factors include:

1. Duration of intruding noises and frequency of occurrence
2. Time of year (windows open or closed)
3. Time of day of noise exposure
4. Outdoor noise level in community when intruding noises are not present
5. History of prior exposure to the noise source
6. Attitude toward the noise source
7. Presence of pure tones or impulses.

Since each of these factors may affect community reactions to noise exposure, adjustments for each have been developed to improve the predictability of community reactions beyond that available from a simple measure of exposure level. Figure 11 shows the results of several different case studies, relating Ldn (in dB) to community response with various correction factors added. The addition of the correction factors makes it possible to predict community reaction to within + 5 dB. As is common with annoyance and interference caused by noise, the effects of context and situation may be almost as important as the magnitude or intensity of the source. Caution is also needed in applying these relationships to communities that are significantly quieter than average urban areas.

Figure 11. Combined Data from Communicty Case Studies Adjusted for Conditions of Exposure



Social Surveys

Extensive social surveys have been conducted around Heathrow Airport near London and at eight major airports in the United States. The relationship found in these surveys between noise exposure levels and the percentage of respondents who were considered annoyed by noise is summarized in Figure 12.

Figure 12. Percent of Population Annoyed by Community Noise (Heathrow Airport Study)

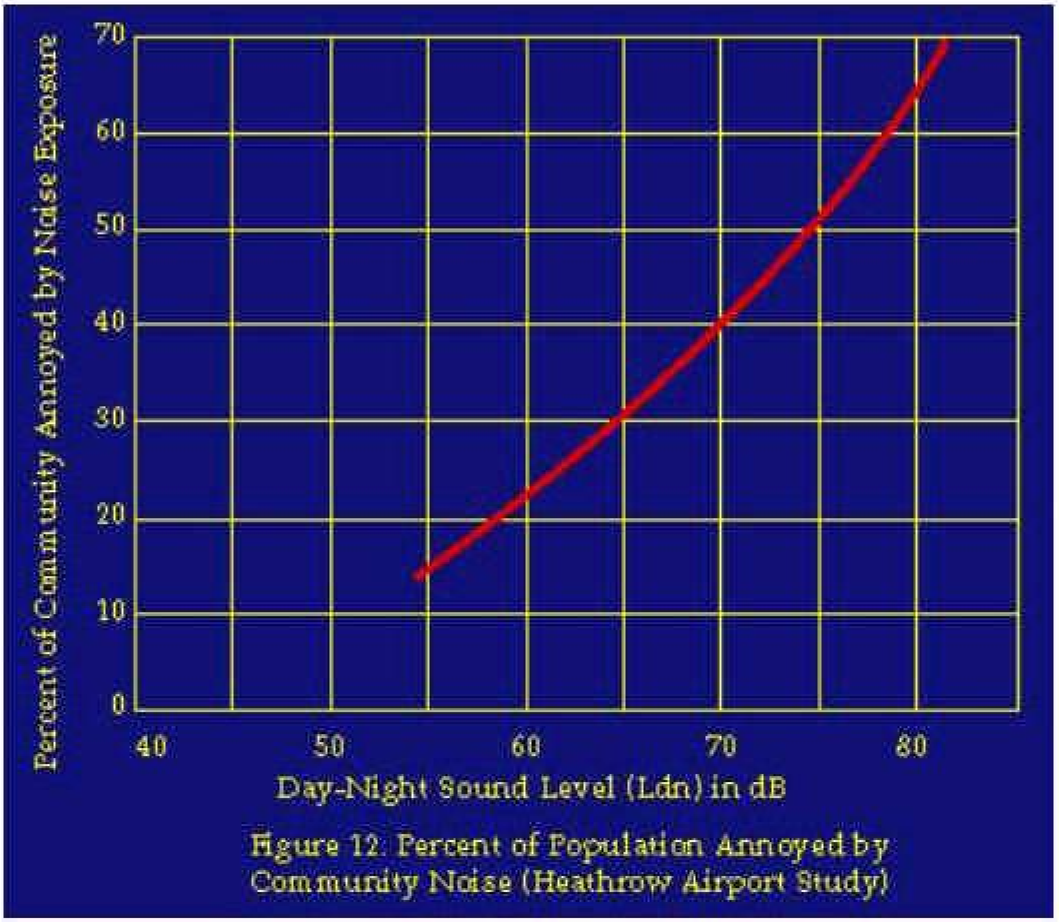


Figure 12. Percent of Population Annoyed by Community Noise (Heathrow Airport Study)

Discussion

Q. Is annoyance simply a "welfare" effect?
A. Annoyance is a reflection of adverse effects which cannot be ascribed solely to "health" or "welfare." "Public health and welfare" in the context of the Noise Control Act is an indivisible term; there are no separate "health" effects or "welfare" effects. "Public health and welfare" includes personal comfort and well-being, and the absence of mental anguish, disturbances and annoyance as well as the absence of clinical symptoms such as hearing loss or demonstrable physiological injury.
Q. What is annoyance due to noise?
A. Noise annoyance may be viewed as any negative subjective reaction to noise on the part of an individual or group. It is not an indication of weakness or inability to cope with stress on the part of the annoyed. More likely it signifies transient (or possibly lasting) stress beyond the control of the conscious individual. This is often expressed on social surveys as the percentage of people who express differing degrees of disturbance or dissatisfaction due to the noisiness of their environments. For the purpose of identifying protective noise levels, annoyance is quantified by using the percentage of people who are annoyed by noise. This is felt to be the best

estimate of the average general adverse response of people, and in turn, is viewed as reflecting activity interference and the overall desire for quiet.
Q. Are people annoyed at levels below an Ldn of 45 or 55 dB? Individuals, or even groups, may be annoyed by noise at low levels-the dripping faucet or humming fluorescent bulb are good examples. Annoyance depends very much on the situation, and on individual differences and noise durations.
Q. What do complaints represent?
A. Complaints are used by officials as an indication that a noise problem exists (although a noise problem may well exist in the absence of specific complaints). However, they do not necessarily represent the magnitude of a noise problem. The number of people who file complaints is only a very small percentage of those who are annoyed.
Q. How is the margin of safety for annoyance applied?
A. The identified indoor level of Ldn = 45 incorporates a margin of safety for 100% protection of speech perception which is used as a surrogate for annoyance. The outdoor identified level of 55 Ldn protects speech outdoors to a level of 95% intelligibility at up to 2 meters, while incorporating a 5 dB margin of safety for speech, and giving added weight to the range of adverse effects.
Q. Why is the nighttime penalty 10 decibels?
A. The 10 dB nighttime weighting had two bases: first, this weighting value has been applied successfully here and in other countries; secondly, in quiet environments, the natural drop in level from day to night is about 10 dB.

Summary

On the basis of its interpretation of available scientific information, EPA has identified a range of yearly Day-Night Sound Levels sufficient to protect public health and welfare from the effects of environmental noise. It is very important that these noise levels, summarized in Table VIII, not be misconstrued. Since the protective levels were derived without concern for technical or economic feasibility, and contain a margin of safety to insure their protective value, they must not be viewed as standards, criteria, regulations, or goals. Rather, they should be viewed as levels below which there is no reason to suspect that the general population will be at risk from any of the identified effects of noise.

Table VIII
Yearly Ldn Values That Protect Public Health and Welfare with a Margin of Safety

EFFECT	LEVEL	AREA
Hearing	Leq(24) < 70 dB	All areas (at the ear)
Outdoor activity interference and annoyance	Ldn < 55 dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
Outdoor activity interference and annoyance	Leq(24) < 55 dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	Ldn < 45 dB	Indoor residential areas
Indoor activity interference and annoyance	Leq(24) < 45 dB	Other indoor areas with human activities such as schools, etc.

Outdoor yearly levels on the Ldn scale are sufficient to protect public health and welfare if they do not exceed 55 dB in sensitive areas (residences, schools, and hospitals). Inside buildings, yearly levels on the Ldn scale are sufficient to protect public health and welfare if they do not exceed 45 dB. Maintaining 55 Ldn outdoors should ensure adequate protection for indoor living. To protect against hearing damage, one's 24-hour noise exposure at the ear should not exceed 70 dB.

Misuses, Misunderstandings, and Questions

Perhaps the most fundamental misuse of the Levels Document is treatment of the identified levels as regulatory goals. They are not regulatory goals; they are levels defined by a negotiated scientific consensus. These levels were developed without concern for economic and technological feasibility, are intentionally conservative to protect the most sensitive portion of the American population, and include an additional margin of safety. In short, the levels in Table VIII are neither more nor less than what Congress required them to be: levels of environmental noise requisite to protect the public health and welfare with an adequate margin of safety.

> Q. Why doesn't the Levels Document explicitly say how much noise is too much noise?
>
> A. Decisions about how much noise is too much noise for whom, for how long, and under what conditions demand consideration of economic, political, and technological matters far beyond the intent of the Levels Document. Such decisions

are properly embodied in formal regulations, not informational publications such as the Levels Document.

Q. How do I use this information for local purposes?

A. This question reflects the need to reconcile local economic and political realities with scientific information. People who formulate local noise abatement programs cannot escape the responsibility of making such economic and political compromises for their constituencies. The Levels Document does not impose arbitrary Federal decisions about the appropriateness of noise environments upon any level of government, nor is it a source of prescriptions for solving local noise problems. It is best viewed as a technical aid to local decision makers who seek to balance scientific information about effects of noise on people with other considerations, such as cost and technical feasibility.

Q. If the identified noise levels are indeed sufficient to protect public health and welfare, shouldn't they be considered to be long-range regulatory goals?

A. Attainment of the identified levels of environmental noise can only be considered idealized goals. Pragmatically, it is unlikely that local, state, or Federal regulatory strategies will seek to attain such levels for all situations in the near future.

Q. Why isn't the Levels Document more definite about specific effects associated with various noise exposure conditions?

A. Available knowledge about the effects of noise would not support more precise statements. Increasingly specific statements will be incorporated in future informational publications as they are justified by increasing knowledge of human response to noise exposure.

noise control

Noise can interfere with sleep, rest and conversation and cause fatigue, irritability, headaches and stress. We all need to contain and reduce noise in order to enjoy a healthy life. Thoughtful design and practice can reduce the impact of noise on our lives and improve the quality of our living environment.

NEIGHBOURHOOD NOISE

Common sources of neighbourhood noise include:

Road, rail and aircraft traffic.

Air conditioners, refrigeration units.

TVs and stereos.

Burglar and car alarms.

Household appliances.

Barking dogs and other animal noises.

Industrial premises and backyard workshops.

Amplified music from houses, commercial premises and concerts.

Road and building maintenance and construction.

Sound pressure level is measured in decibels (dB) and some typical values are given below.

SOUND LEVEL (dB)	PERCEPTION EXAMPLE
120	Extreme jet take off at 100 m
110	Pop group
100	Loud car horn
90	Very loud heavy traffic
80	Noisy office
70	Loud busy street
60	Average office
50	Noisy normal conversation
40	Moderate quiet office
30	Quiet conversation
20	Quiet room
10	Very faint normal breathing
0	Threshold of hearing

NEIGHBOURHOOD NOISE

Communities usually agree about what noise volumes are acceptable and what are not but there are several subjective elements that determine our response to noise. Our perception of noise is affected by subjective factors. These include the type of noise, our mood, the time of day, background noise levels and our expectations.

Options to Reduce Noise

Recognising these subjective factors helps us determine when others are creating noise unfairly and how to respond. If neighbourhood noise is a genuine problem for you there are some actions you can take:

Choose a quiet neighbourhood.

Reduce the noise by talking it over with whoever is causing the problem, or by lodging a complaint.

Block the noise with barriers, sound absorbent materials and appropriate home design.

You should also minimise your own contribution to neighbourhood noise.

Carry out noisy activities during the day.

Inform your neighbours whenever you need to generate noise, such as a party at home.

Design your home to minimise noise transfer to your neighbours.

Road Traffic Noise

For most Australians road noise is the most important neighbourhood noise issue as it affects a high proportion of the population, and the problem is growing as traffic levels increase. [See: Transport]

Surveys show that noise is the main environmental concern for most Australians. Many people complain that traffic noise has the greatest direct impact.

Minimise the impact of traffic noise on your home - and your contribution to the problem.

Cycle or walk, rather than drive.

Buy a quiet car, and drive it less.

Drive slowly and calmly and maintain your car.

Shop locally and buy locally made products to reduce freight travel.

Report noisy vehicles.

noise control

Work with your neighbourhood and council, and community organisations and government to create more livable communities with reduced traffic noise. Central to this is the creation of urban villages based on public transport, walking, cycling, traffic calming and other traffic reduction initiatives. [See: Transport]

NOISE IN BUILDINGS

Non-traffic related noise complaints are rising, particularly in medium and high density housing areas. Many new medium and high density developments are unnecessarily noisy.

It can be very difficult or expensive to do anything about a noise nuisance after a house is built or purchased. Consider potential noise problems before you buy, build or renovate.

Ask for design specifications for noise levels before buying a multi residential unit and ask your solicitor to link them to your contract as a performance measure. This will give you more options if you discover a problem after moving in.

The section of the Building Code of Australia (BCA) covering indoor noise transmission regulations for shared walls and floors is being revised and improved.

The following design sound levels are recommended for an inner suburban house

ACTIVITY	RECOMMENDED DESIGN LEVELS (dB) SATISFACTORY	MAXIMUM
Recreation areas	35	40
Bedrooms	30	35
Work areas	35	40

From Table 1 AS 2107

TYPES OF NOISE

There are two types of building noise to consider: airborne and structure-borne.

Airborne noise comes from common sound sources such as voices, TVs and radios. The noise performance of a building system is called the Sound Transmission Class (STC). The higher the STC the better the system is at isolating airborne noise. An STC rating of 45 means that the element reduces the sound passing through it by 45 dB

Rooms with a lot of hard surfaces can be very noisy as they readily reflect sound. Soft furnishings, drapes and rugs can make a significant improvement.

A change of 3 STC (or dB) in the sound level means a doubling or halving of the sound energy. As the human ear does not perceive sound in a linear way, a 3 dB change is barely perceptible. The table below shows the subjective perception of sound energy.

REDUCTION IN dB	%	REDUCTION IN SOUND ENERGY SUBJECTIVE PERCEPTION
3	50	Barely perceptible
4-5	70	Significant
6	75	Sound appears to be reduced by about 1/4
7-9	87	Major reduction
10	90	Sound appears to be less than half original

The table below outlines what this means in practice for building elements.

STC	EFFECT ON SPEECH PERCEPTION
25	Normal speech can be heard easily
30	Loud speech can be heard easily
35	Loud speech can be heard but not understood
42	Loud speech heard as murmeur
45	Must strain to hear loud speech
48	Loud speech can be barely heard
53	Loud speech cannot be heard

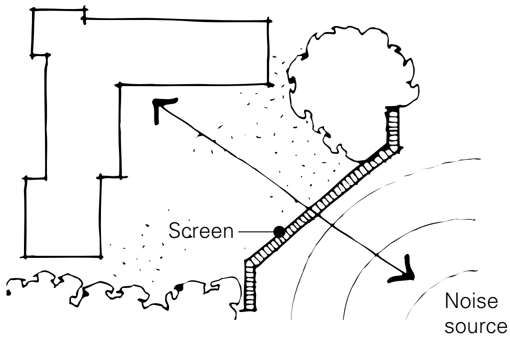
Structure-borne noise, also called impact noise, is produced when part of the building fabric is directly or indirectly impacted. Energy passes through the building structure and creates noise in nearby rooms. Examples are heavy footsteps (particularly on bare timber or tile floors), banging doors, scraping furniture, vibrations from loud music, and plumbing noise. The Impact Insulation Class (IIC) is used to rate the impact noise insulation of floors.

IIC	
45	People walking around are clearly audible
50	People walking around are audible and noticeable
55	People walking around audible but acceptable
62	Walking heard as low frequency thump
70	Heavy walking heard as low frequency thump

NOISE AND GOOD DESIGN

SITE PLANNING

Consider noise sources such as shops, hotels, garbage and recycling collection when siting buying or renovating your home.



Place screens such as fences, trees and hedges between the noise source and your home. Place driveways/garages away from bedrooms and living rooms.

BUILDING LAYOUT AND DESIGN

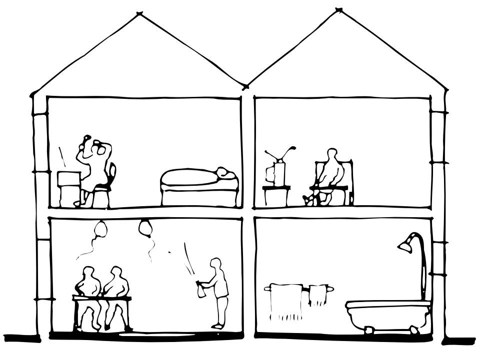
Locate quiet rooms as far away from noise sources as possible, without compromising passive solar design principles.

Install windows away from noise sources if possible.

Locate noisy areas together and away from quiet areas.

Avoid putting laundries, bathrooms or living rooms next to, above or below bedrooms without adequate sound insulation.

Accommodate teenagers by providing extra soundproofing for their rooms and locate them away from adult living and sleeping areas, and neighbours.



Noise is a particular problem within medium and high density housing, and special care in design is needed to avoid problems. If people are unable to open windows to keep cool in summer they may need to install mechanical cooling.

Minimise the need for noisy mechanical cooling.

Use solid dividing fins between balconies.

Build units around quiet courtyards and face them away from roads.

Keep pedestrian and vehicle thoroughfares away from bedrooms and living rooms.

Avoid placing windows and doors of neighbouring units opposite or adjacent to one another.

CONSTRUCTION

The BCA Building Code of Australia (BCA) specifies the minimum STC wall and floor requirements between adjoining dwellings. The BCA uses a sound reduction index (Rw) which is directly equivalent to STC.

Exceeding the minimum specifications is highly recommended, particularly given the trend towards higher density living.

The BCA does not specify IIC, but certain construction types are "deemed to comply".

R_W levels in the BCA only consider individual building elements as measured in a laboratory. Sound transmission properties of the structure as a whole or on-site construction practices are not taken into account. These can reduce the effective value by up to 5 R_W due to flanking sound transmission paths.

Good design detail and construction practice is critical to the performance of both heavy and light construction.

Pay attention to elements like floor and ceiling plates and installation of services such as plumbing and power outlets to ensure the desired performance is achieved.

BCA R_W requirements for walls between adjoining dwellings are:

	MINIMUM R_W
Floors above dwellings	50
Walls between a bathroom, laundry or kitchen and a habitable room in adjoining dwelling*	50
Other walls	45

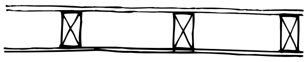
**These walls must also have a satisfactory level of impact insulation as outlined in the code*

Although the BCA specifies no sound insulation requirements within dwellings it is important to consider sound transmission in homes now that multiple TVs, stereos and bathrooms are common.

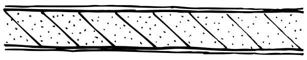
The R_W ratings of some typical wall and floor construction methods are outlined below.

noise control

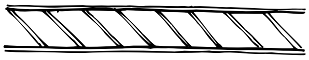
WALLS



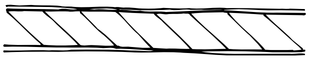
R_w32. Using 10mm plasterboard on 100x50mm timber studs at 450mm centres provides very little sound insulation and is not recommended for occupied rooms.



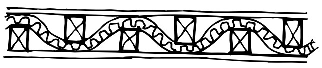
R_w42. 100mm low density AAC block with 10mm adhered plasterboard both sides.



R_w45. 90mm calcium silicate brick with adhered 10mm plasterboard both sides. This complies with the BCA minimum for adjoining dwellings.

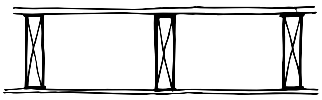


R_w50. 90mm solid concrete block with adhered 10mm plasterboard both sides.

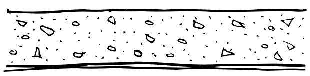


R_w50. 16mm fire protective plasterboard on staggered timber 70 x 45mm studs at 600mm centres both sides with 120x35mm timber plates and 50mm glass fibre batts.

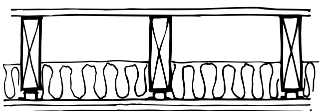
FLOORS



R_w35. Bare 20mm floorboards on 200x50mm joists at 450mm centres, with one layer of 13mm plasterboard. This provides very little sound or impact insulation and is not recommended.



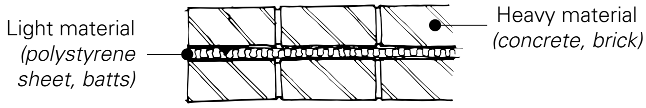
R_w48. 150mm concrete slab (365kg/m2) with 10mm of plaster.

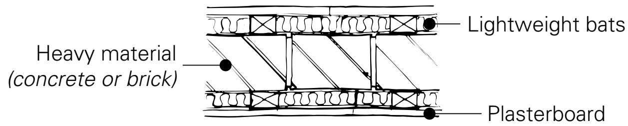


R_w50. IIC 50. Bare 20mm floorboards on 200x50mm joists at 450mm centres, with two layers of 16mm fire protective plasterboard on furring channels and resilient mounts, and 100mm batts. Using carpet and underlay will increase the IIC to 70.

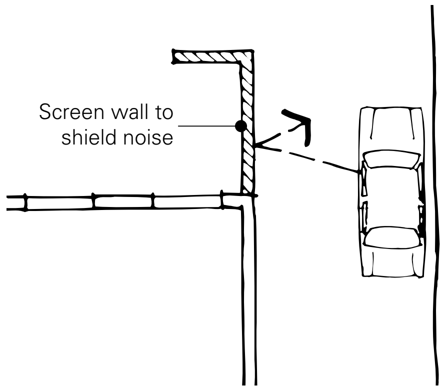
Heavy dense materials, such as concrete, are generally better for sound insulation but a range of lightweight solutions are also available.

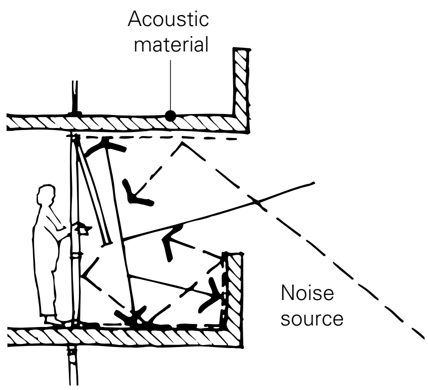
Dense materials will, however, readily transmit impact noise.





Composite construction using combinations of light and heavy mass materials are best to reduce noise transmission.





Airborne noise is easily reflected. Provide screen walls to shield noise and use acoustic materials to reduce noise reflection.

GLASS AND NOISE

A 3 mm single glazed window has a very low STC, and windows can let in a lot of noise, open or closed. The potential sound reduction from a highly insulating wall can be substantially reduced by poor window design.

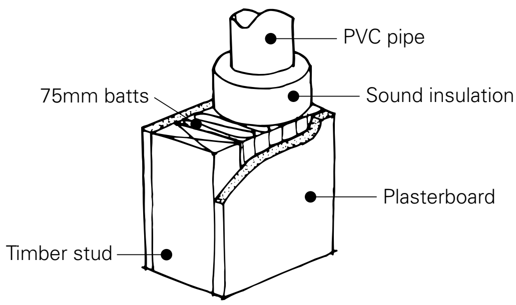
Double glazing and laminated glass are both effective at reducing noise. The table below shows the percentage noise reduction compared to 3mm glass. Note that these percentage reductions are **not** the same as STC values.

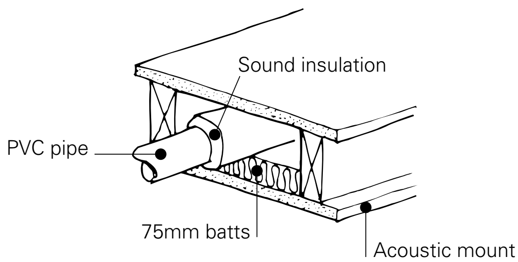
VOICE NOISE REDUCTION	%	TRAFFIC NOISE REDUCTION	%
GLAZING TYPE (SINGLE)		GLAZING TYPE (SINGLE)	
6.38mm laminated	13	6.38mm laminated	24
10mm glass	24	10mm glass	38
10.38mm laminated	29	10.38mm laminated	43
GLAZING TYPE (DOUBLE)		GLAZING TYPE (DOUBLE)	
4mm /12mm space /4mm	19	10mm /12mm space/ 6.38mm laminated	46
10mm /12mm space/6mm	34	6mm /100mm space/4mm	57
6.38mm laminated /8mm space/4mm	46		

Source Pilkingtons

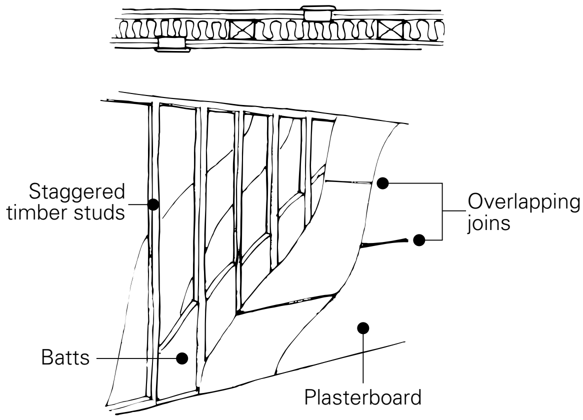
Note: Thicker glass generally does not improve thermal insulation. For a combination of sound and thermal insulation use double glazing. [See: Glazing]

OTHER NOISE ABATEMENT TIPS





Plumbing and waste pipes should not pass close to quiet rooms or should be adequately soundproofed. A range of sound insulation products exist for plumbing and waste pipes in walls and floors.



Pay special attention to details that might affect the integrity of sound insulation such as power points and plasterboard joints. Power outlets should be offset and placed in different sections of the wall cavity. When using double layers of plasterboard ensure the joints overlap and offset joints on opposite sides of the wall.

Provide extra sound insulation for noisy rooms such as laundries. Use acoustic mounts or pads for clothes washers and dryers.

Avoid hard floor surfaces that are above ceilings without good sound insulation. Use cork, carpet or impact absorbing finishes instead of bare timber or tiles.

Low density coverings such as carpet will have little effect on STC but will greatly reduce both impact noise (increasing the IIC by about 20 points) and internal sound reflection.

Proprietary noise reduction underlays can be used to increase both STC and IIC ratings of floors. They are ideal for reducing sound transmission on existing floors within a home.

Use built-in robes as sound buffers between bedrooms.

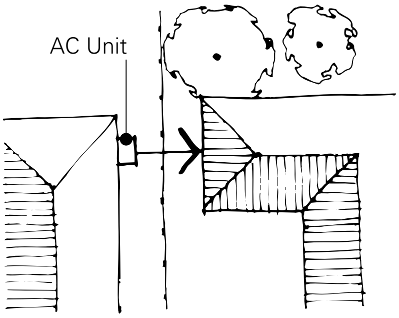
Solid core doors are more effective sound insulators than hollow core. Use door closers or foam/plastic strips on door frames to stop doors banging.

Reduce sound reflection transmission through gaps with draught sealing strips.

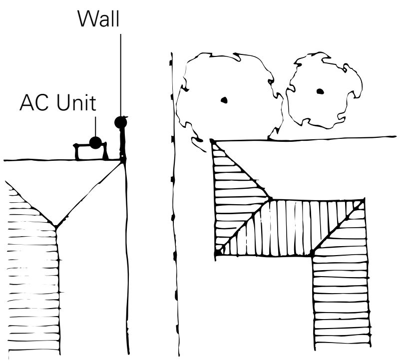
OUTDOOR NOISE SOURCES

Site noisy areas like swimming pools and outdoor living areas away from neighbour's windows.

Hard exterior surfaces such as concrete paving reflect sound rather than absorb it. Softer surfaces are more desirable, particularly in higher density housing, as they absorb sound. Permeable surfaces also reduce stormwater run-off. [See: Stormwater]



Unsuitable location for air conditioning unit



Suitable location for air conditioning unit

Make sure outdoor noise sources (AC units, pool pumps) are not going to be a nuisance for neighbours. If pumps can't be placed far enough away, build a noise reduction enclosure.

There are laws governing noisy air conditioners that may annoy neighbours. The best solution is to buy the quietest air conditioner suited to your needs. Install it as far as possible from your neighbour or in a well shielded location. Most air conditioners in Australia have a label that specifies the amount of noise they make. The smaller the number of dBA on the label the quieter the air conditioner. Get specialist advice from the supplier or installer.

ADDITIONAL KEY REFERENCES
NSW EPA (1999) Environmental Criteria for Road Traffic Noise, Sydney
NSW EPA (1999) *Neighbourhood Noise*, pamphlet, Sydney
Building Code of Australia Volume 2 Part 3.8.6 *Sound Insulation*
CSR Gyprock Fire and Acoustic Design Guide www.csr.com.au/product_homeswork/building/gyprock/gyp_lite.asp
Cement and Concrete Association of Australia *Acoustic Benefits of "Solid" Construction* (1999)
QuietZone *Sound Design Guide* Tel: 1300 657 465

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