Overview of Noise and Vibration

Noise Fundamentals

Noise may be described as unwanted sound and is usually objectionable because it is disturbing or annoying. Sound is defined as any pressure variation in air that the human ear can detect. In general, the objectionable nature of sound can be due to its pitch or its loudness. Pitch is related to the frequency of the vibrations by which sound is produced; in general, intermediate pitched signals sound louder to humans than sounds with a lower or higher pitch. Loudness is the amplitude or intensity of sound waves combined with the reception characteristics of the ear; the higher the amplitude, the louder the sound.

Technical acoustical terms commonly used in this section are defined in Table 1. Acoustics consists of a sound (i.e., noise) source, a receptor, and the propagation path between the two. The loudness of the noise source and the obstructions or atmospheric (environmental) factors, which affect the propagation path to the receptor, determine the sound level and the characteristics of the noise perceived by the receptor.

Although the decibel (dB) scale is commonly used, the dB scale alone does not adequately characterize how humans perceive noise. To approximate the response of the human ear, sound levels of individual frequency bands are weighted, depending on human sensitivity to those frequencies. The common measure is the A-weighted sound level (dBA), which approximates the response of the average young ear to most ordinary sounds (Table 2). Peoples' judgments regarding the relative loudness or annoyance of a sound tend to correlate well with the A-scale sound levels of those sounds.

Because decibels are logarithmic units, sound pressure levels cannot be added or subtracted through ordinary arithmetic. On the dB scale, a doubling of sound energy corresponds to a 3 dB increase, so that when two identical sources are each producing sound of the same loudness, their combined sound level at a given distance would be 3 dB higher than either source under the same conditions. For example, if one excavator produces a sound pressure level of 80 dBA, two excavators would not produce 160 dBA. Rather, they would combine to produce 83 dBA. The cumulative sound level of any number of sources, such as excavators, can be determined using decibel addition.

Table 1: Definitions of Acoustical Terms

Term	Definition
Sound	A vibratory disturbance created by a vibrating object, which when transmitted by pressure waves through a medium such as air, is capable of being detected by a receiving mechanism such as the human ear or a microphone.
Noise	Sound that is loud, unpleasant, unexpected, or otherwise undesirable.
Sound Pressure Level	Sound pressure is the sound force per unit area, usually expressed in micropascals, where 1 pascal is the pressure from a force of 1 newton exerted over an area of 1 square meter. The sound pressure level is more commonly expressed in decibels (see below). Sound pressure level is the quantity that is measured directly by a sound level meter.
Decibel (dB)	A unit describing the amplitude of sound equal to 20 times the logarithm to base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for air is 20 micropascals.
Frequency, Hertz (Hz)	The number of complete pressure fluctuations per second above and below atmospheric pressure. Normal human hearing is 20 Hertz (Hz) - 20,000 Hz.
A-Weighted Sound Level (dBA)	The sound pressure level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low- and very high-frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise.

Term	Definition
Equivalent Noise Level (L_{eq})	The average A-weighted noise level during the measurement period. The hourly L_{eq} used for this report is denoted as dBA L_{eq}[h].
Community Noise Equivalent Level (CNEL)	The average A-weighted noise level during a 24-hour day, which is obtained by adding 5 dB to sound levels in the evening from 7:00 PM to 10:00 PM and 10 dB to sound levels between 10:00 PM and 7:00 AM
Day/Night Noise Level (L_{dn})	The average A-weighted noise level during a 24-hour day, which is obtained by adding 10 dB to sound levels measured at night between 10:00 PM and 7:00 AM
Maximum Sound Level (Lmax)	The maximum A-weighted noise level measured during the measurement period.
Minimum Sound Level (Lmin)	The minimum A-weighted noise level measured during the measurement period.
Ambient Noise Level	The composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.
Intrusive Noise	That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, time of occurrence, and tonal or informational content as well as the prevailing ambient noise level.

Environmental sounds are commonly described in terms of an average level that has the same acoustical energy as the summation of all the time-varying events. This equivalent noise level descriptor is called Leq. A common averaging period is hourly, but Leq can describe any series of noise events of arbitrary duration. Sound level meters can accurately measure environmental noise levels to within approximately plus or minus 1 dBA.

Table 2: Typical Noise Levels in the Environment

Common Outdoor Noise Source	Noise Level (dBA)	Common Indoor Noise Source
	120 dBA	
Jet fly-over at 300 meters		Rock concert
	110 dBA	
Pile driver at 30 meters	100 dBA	
		Night club with live music
	90 dBA	
Large truck passes by at 15 meters		
	80 dBA	Noisy restaurant
		Garbage disposal at 1 meter
Gas lawn mower at 30 meters	70 dBA	Vacuum cleaner at 3 meters
Commercial/Urban area daytime		Normal speech at 1 meter
Suburban expressway at 90 meters	60 dBA	
Suburban daytime		Active office environment
	50 dBA	
Urban area nighttime		Quiet office environment
	40 dBA	
Suburban nighttime		
Quiet rural areas	30 dBA	Library
		Quiet bedroom at night
Wilderness area	20 dBA	
	10 dBA	Quiet recording studio

Common Outdoor Noise Source	Noise Level (dBA)	Common Indoor Noise Source
Threshold of human hearing	0 dBA	Threshold of human hearing

Human Responses to Noise

It is widely accepted that a change of 3 dBA in the normal environment is just noticeable to most people; an increase of 3 dBA is perceived as approximately a 25 percent increase in noise level; a change of 5 dBA is readily perceptible; and a change of 10 dBA is perceived as being twice as loud. Accordingly, a doubling of sound energy (e.g., doubling the volume of traffic on a highway), which would result in a 3 dB increase in sound would generally be barely detectable.

A number of studies have linked increases in noise with health effects, including hearing impairment, sleep disturbance, cardiovascular effects, psychophysiological effects, and potential impacts to fetal development.[1] Potential health effects appear to be caused by both short and long-term exposure to very loud noises and long-term exposure to lower levels of sound (chronic exposure). Acute exposure to sound levels greater than 120 dBA (equivalent to a rock concert, Table 3.5-2) can cause mechanical damage to the ear and hearing impairment.[2]

According to the World Health Organization and the USEPA, Leq = 70 dBA is a safe daily average noise level for the ear.[3][4] However, even this level may cause disturbance to sleep and concentration and be linked to chronic health impacts such as hypertension and heart disease.[5]

Sound Propagation

When sound propagates over a distance, it changes in both level and frequency content. The manner in which noise is reduced with distance depends on the following important factors:

Geometric spreading from point sources. Sound from a single source (i.e., a "point" source) radiates uniformly outward as it travels away from the source in a spherical pattern. The sound level attenuates (or drops off) at a rate of 6 dBA for each doubling of distance (intensity drops to one-quarter of the previous level with each doubling of distance).

Geometric spreading from line sources. Some sound generators are not point sources. Highway noise, for example, is not a single stationary point source of sound. The movement of vehicles on a highway makes the source of the sound appear to emanate from a line (i.e., a "line" source) rather than from a point. This results in cylindrical spreading rather than the spherical spreading resulting from a point source. The change in sound level from a line source is 3 dBA per doubling of distance (intensity drops to one-half of the previous level with each doubling of distance).

Ground absorption. Usually the noise path between the source and the observer is very close to the ground. The excess noise attenuation from ground absorption occurs due to acoustic energy losses on sound wave reflection. Traditionally, the excess attenuation has also been expressed in terms of attenuation per doubling of distance. This approximation is done for simplification only; for distances of

[1] Babisch, Wolfgang, Transportation Noise and Cardiovascular Risk, Federal Environmental Agency, Berlin, Germany. January 2006. https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/2997.pdf (last accessed April 2019).

[2] Babisch, 2006.

[3] Berglund, B., Lindvall, T., & Schwela, D. H. Guidelines for community noise. World Health Organization, Geneva, Switzerland. 1999.

[4] U.S. Environmental Protection Agency, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, Prepared by Office of Noise Abatement Control. March 1974. https://nepis.epa.gov/Exe/ZyPDF.cgi/2000L3LN.PDF?Dockey=2000L3LN.PDF (last accessed April 2019).

[5] Babisch, 2006.

less than 200 feet, prediction results based on this scheme are sufficiently accurate. For acoustically "hard" sites (i.e., sites with a reflective surface, such as a parking lot or a smooth body of water, between the source and the receptor), no excess ground attenuation is assumed because the sound wave is reflected without energy losses. For acoustically absorptive or "soft" sites (i.e., sites with an absorptive ground surface, such as soft dirt, grass, or scattered bushes and trees), an excess ground attenuation value of 1.5 dBA per doubling of distance is normally assumed. When added to the geometric spreading, the excess ground attenuation results in an overall drop-off rate of 4.5 dBA per doubling of distance for a line source and 7.5 dBA per doubling of distance for a point source. Although some ground attenuation is expected, it is often ignored in a noise analysis, to ensure a conservative analysis and considering that, in any event, it is very difficult to characterize accurately.

Atmospheric effects. Research by Caltrans and others has shown that atmospheric conditions can have a major effect on noise levels. Wind has been shown to be the single most important meteorological factor within approximately 500 feet, whereas vertical air temperature gradients are more important over longer distances. Other factors, such as air temperature, humidity, and turbulence, also have major effects. Receptors located downwind from a source can be exposed to increased noise levels relative to calm conditions, whereas locations upwind can have lower noise levels. Increased sound levels can also occur because of temperature inversion conditions (i.e., increasing temperature with elevation) which cause reflection of sound from the inversion layer back to the ground. As with ground absorption, atmospheric effects are often ignored, as here, in the interest of a conservative analysis.

Shielding by natural or human-made features. A large object or barrier in the path between a noise source and a receptor can substantially attenuate noise levels at the receptor. The amount of attenuation provided by this shielding depends on the size of the object, proximity to the noise source and receptor, surface weight, solidity, and the frequency content of the noise source. Natural terrain features (such as hills and dense woods) and human-made features (such as buildings and walls) can substantially reduce noise levels. As appropriate, walls are often constructed between a source and a receptor with the specific purpose of reducing noise. A barrier that breaks the line of sight between a source and a receptor will typically result in at least 5 dBA of noise reduction. A higher barrier may provide as much as 20 dBA of noise reduction. Lightly built barriers provide less attenuation.

Vibration Fundamentals

Groundborne vibration is an oscillatory motion of the soil with respect to the equilibrium position and can be quantified in terms of velocity or acceleration. It can be a serious concern for nearby neighbors of activities that cause buildings to shake and rumbling sounds to be heard, but it is unusual for vibration from sources such as buses and trucks on smooth roads to be perceptible, even in locations close to major roads. Most perceptible indoor vibration is caused by sources within buildings, such as the operation of mechanical equipment, movement of people, or the slamming of doors. Typical outdoor sources of perceptible groundborne vibration are heavy construction equipment and activities (such as blasting and pile driving), steel-wheeled trains, and heavy trucks on rough roads. There are several different methods that are used to quantify vibration. The peak particle velocity (PPV) is defined as the maximum instantaneous peak of the vibration signal. The PPV is most frequently used to describe vibration impacts to buildings. The root mean square (RMS) amplitude is most frequently used to describe the effect of vibration on the human body. The RMS amplitude is defined as the average of the squared amplitude of the signal. Decibel notation (VdB) is commonly used to measure RMS.

Table 3 summarizes common sources of groundborne vibration velocity levels (measured in decibel units [VdB]) and average human response to vibration that may be anticipated when a person is at rest in quiet surroundings (tolerance to vibration increases considerably during physical activity). The duration of the vibration event has an effect on human response, as does its frequency of occurrence: increases in both result in decreased tolerance. Typical background vibration levels in residential areas are usually 50 VdB or lower, well below the threshold (65 VdB) of perception for most humans.

Groundborne noise is a secondary phenomenon of groundborne vibration. When a building or structure vibrates, noise radiates into the interior of the building, producing rattling of windows, doors, stacked dishes, etc. Low-frequency vibration could produce groundborne noise perceived as a low rumble. Groundborne noise is quantified by the A-weighted sound level inside the building. The sound level accompanying vibration is generally 25 to 40 dBA lower than the vibration velocity level in VdB. Groundborne vibration levels of 65 VdB can result in groundborne noise levels up to 40 dBA, which can disturb sleep. Groundborne vibration levels of 85 VdB can result in groundborne noise levels up to 60 dBA, which can be annoying to daytime noise sensitive land uses such as schools.[6]

Table 3: Typical Levels of Ground-borne Vibration

Human or Structural Response	Vibration Velocity Level (VdB)	Typical Sources (50 feet from source)
Threshold for minor cosmetic damage to fragile buildings	100	Blasting, pile driving, vibratory compaction equipment
	95	Bulldozers, and other heavily tracked construction equipment
Difficulty with tasks such as reading a video or computer screen	90	Commuter rail, upper range
Residential annoyance, infrequent events	80	Rapid transit, upper range
Residential annoyance, occasional events	76	Commuter rail, typical
Residential annoyance, frequent events	72	Bus or truck over bump or on rough roads
	70	Rapid transit, typical
Limit for vibration sensitive equipment	60	Bus or truck, typical
	50	Typical background vibration

Source: USDOT Federal Transit Administration, 2006.

Sensitive Receptors

Some land uses are considered more sensitive to ambient noise (and groundborne vibration) levels than others. People in residences, motels and hotels, schools, libraries, churches, hospitals, nursing homes, auditoriums, natural areas, parks and outdoor recreation areas are generally more sensitive to noise than are people at commercial and industrial establishments. Consequently, the noise standards for sensitive land uses are more stringent than for those at less sensitive uses. Notably, schools, parks, and recreational land uses are not considered as sensitive to noise as residential uses and places where people sleep.

[6] Federal Transit Administration (FTA). 2006. Transit Noise and Vibration Impact Assessment, FTA-VA-90-1003-06. May. Available online at: http://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/analysis_and_abatement_guidance/revguidance.pdf (last accessed April 2019).

Noise and Vibration Documentation

Following are the documents associated with the Noise and Vibration analysis of the proposed East West Valley Interceptor Sewer Project Draft EIR:

- Noise and Vibration Measurement Locations
- Long-term Noise Measurement Data – Hourly Noise Levels
- Short-term Noise Monitoring Field Data Sheets
- Short-term Vibration Monitoring Field Data Sheets
- Construction Noise Analysis
- FHWA Traffic Noise Calculator spreadsheets
- Construction Vibration Analysis