A Fundamentals and Definitions (Noise and Lighting)

Lighting Background Information

Unwanted light in the nighttime environment is becoming a growing concern worldwide. Numerous local communities, cities, counties, and states have developed ordinances to control unwanted light. Unwanted or stray light can take the form of sky glow, light trespass, and glare.

"Sky glow" is the term used to describe the added sky brightness caused by the scattering of electric light into the atmosphere, particularly from outdoor lighting in urban areas. This phenomenon is of concern to astronomers and, to a lesser extent, the general public.

Light that strays from its intended purpose can become a visual annoyance or even temporarily disabling. The term "light trespass" is used to describe this effect. Most complaints about light trespass come from people upset by stray light entering their windows or intruding upon their property. In an effort to solve light trespass problems, various communities are now adopting outdoor lighting ordinances or regulations. Some of these specify measurable limits for light trespass in terms of horizontal illuminance at or within property lines.

A severe form of light trespass involves glare. Glare is the sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted, causing annoyance, discomfort, or loss in visual performance and visibility. It is often considered to restrict the vision of people performing driving tasks.

Light Measurement

A "lumen" is the unit of light output from a source. Lumens indicate a rate of energy flow and are therefore a power unit, like the watt or horsepower. The illumination level is the amount or quantity of light falling on a surface and is measured in footcandles or lux. The footcandle is equal to one lumen per square foot, and the lux is equal to one lumen per square meter. In monitoring light trespass, illuminance is measured with a footcandle meter and the results are then compared to allowable levels of light trespass found in local ordinances or other appropriate guidance documents.

References

Illuminating Engineering Society of North America, 2000, IESNA Technical Memorandum Addressing Obtrusive Light (Urban Sky Glow and Light Trespass) in Conjunctions with Roadway Lighting, IESNA TM-10-2000, New York, NY.

Illuminating Engineering Society of North America, 2000, IESNA Technical Memorandum on Light Trespass: Research, Results and Recommendations. IESNA TM-11-2000, New York, NY.

United States Code Title 33 - Navigation and Navigable Waters, Chapter 34 - Inland Navigational Rules, Part C - Lights and Shapes, Sections 2020 through 2024.

United States Code of Federal Regulations, 2003, 33 CFR - Chapter I - Part 154.

Noise Background Information

Noise is defined as any unwanted sound, and *sound* is defined as any pressure variation that the human ear can detect. The human ear is capable of detecting pressure variations of less than one billionth of atmospheric pressure. Air pressure changes that occur between 20 and 20,000 times a second, stated as units of hertz (Hz), are registered as sound.

Sound is often measured and described in terms of its overall energy, taking all frequencies into account. However, the human hearing process is not the same at all frequencies. Humans are less sensitive to low frequencies (less than 250 Hz) than mid-frequencies (500 Hz to 1,000 Hz). Humans are most sensitive to frequencies in the 1,000 to 5,000 Hz range. Therefore, noise measurements are often adjusted or weighted as a function of frequency to account for human perception and sensitivities. The most common weighting networks used are the A- and C-weighting networks. These weight scales were developed to allow sound level meters to simulate the frequency sensitivity of the human hearing mechanism. They use filter networks that approximate the hearing characteristic. The A-weighted network is the most commonly used and sound levels measured using this weighting are noted as dB(A). The letter "A" indicates that the sound has been filtered to reduce the strength of very low and very high frequency sounds, much as the human ear does.

Because the human ear can detect such a wide range of sound pressures, sound pressure is converted to sound pressure level (SPL), which is measured in units called decibels. The decibel is a relative measure of the sound pressure with respect to a standardized reference quantity. Decibels on the A-weighted scale are termed dBA. Because the scale is logarithmic, a relative increase of 10 decibels represents a sound pressure that is 10 times higher. However, humans do not perceive a 10-dBA increase as 10 times louder. Instead, they perceive it as twice as loud. The following is typical of human response to relative changes in noise level:

- A 3-dBA change is the threshold of change detectable by the human ear,
- A 5-dBA change is readily noticeable, and
- A 10-dBA change is perceived as a doubling or halving of noise level.

The SPL that humans experience typically varies from moment to moment. Therefore, various descriptions are used to evaluate noise levels over time. Some typical descriptors are defined below:

1. L_{eq} is the continuous equivalent sound level. The sound energy from the fluctuating SPLs is averaged over time to create a single number to describe the mean energy, or intensity level. High noise levels during a monitoring period will have a greater effect on the L_{eq} than low noise levels. The duration of the measurement would be shown as $L_{eq(1).}$ A 24-hour measurement would be shown as $L_{eq(24)}$. The L_{eq} has an advantage over other descriptors because L_{eq} values from various noise sources can be added and subtracted to determine cumulative noise levels.

2. L_{dn} is the day-night equivalent sound level. It is similar to an $L_{eq(24)}$ but with 10 dBA added to all SPL measurements between 10:00 p.m. and 7:00 a.m. to reflect the greater intrusiveness of noise experienced during these hours.

3. L_{max} is the highest SPL measured during a given period of time. It is useful in evaluating L_{eq} for time periods that have an especially wide range of noise levels.

4. L_{10} is the SPL exceeded 10% of the time. Similar descriptors are the L_{50}, L_{01}, and L_{90}.

When adding sound pressure levels created by multiple sound sources there is no mathematical additive effect. For instance, two proximal noise sources that are 70 dBA each do not have a combined noise level of 140 dBA. In this case, the combined noise level is 73 dBA (see table below).

Approximate Addition of Sound Levels

Difference Between Two Sound Levels	Add to the Higher of the Two Sound Levels
1 dB or less	3 dB
2 to 3 dB	2 dB
4 to 9 dB	1 dB
10 dB or more	0 dB

(USEPA, Protective Noise Levels, 1974)

The decrease in sound level due to distance from any single noise source normally follows the "inverse square law." That is, the SPL changes in inverse proportion to the square of the distance from the sound source. In a large open area with no obstructive or reflective surfaces, it is a general rule that at distances greater than 50 feet the SPL from a point source of noise drops off at a rate of 6 dB with each doubling of distance away from the source. For "line" sources (such as vehicles on a street), the SPL drops off at a rate of 3 dB(A) with each doubling of the distance from the source. Sound energy is absorbed in the air as a function of temperature, humidity, and the frequency of the sound. This attenuation can be up to 2 dB over 1,000 feet. The drop-off rate will also vary with both terrain conditions and the presence of obstructions in the sound propagation path.

Wind can further reduce the sound heard at a distance if the receptor is upwind of the sound. The action of the wind disperses the sound waves, reducing the SPLs upwind. While it is true that sound levels upwind of a noise source will be reduced, receptors downwind of a noise source will not realize an increase in sound level over that experienced at the same distance without a wind.

In certain circumstances, sound levels can be accentuated or focused by certain features to cause adverse noise impacts at specified locations. At a hard rock mine, curved quarry walls may have the potential to cause an amphitheater effect while straight cliffs and quarry walls may cause an echo.

The three principal types of noise sources that affect the environment are mobile sources, stationary sources, and construction sources. Mobile sources are those noise sources that move in relation to a noise-sensitive receptor—principally automobiles, buses, trucks, aircraft, and trains. Stationary sources of noise, as the name implies, do not move in relation to a noise sensitive receptor. Typical stationary noise sources of concern include machinery or mechanical equipment associated with industrial and manufacturing operations or building heating, ventilating, and air-conditioning systems. Construction noise sources comprise both mobile (e.g., trucks, bulldozers, etc.) and stationary (e.g., compressors, pile drivers, power tools, etc.) sources.

References

City of New York. October 2001. City Environmental Quality Review Technical Manual.

New York State Department of Environmental Conservation. June 2003. Assessing and Mitigating Noise Impacts.

New York State Department of Transportation Environmental Analysis Bureau. 1998. Environmental Procedures Manual, Chapter 3.1, Attachment 3.1.D (New York State Noise Analysis Policy).

United States Code of Federal Regulations. 1999. Part 772-Procedures for Abatement of Highway Traffic Noise and Construction Noise, 23 CFR Ch. I (4-1-99 edition).